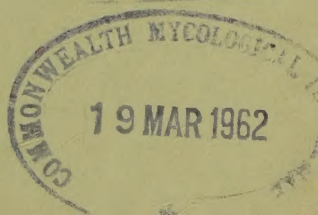
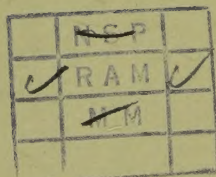


ANNUAL REPORT

of the

WEST AFRICAN
COCOA RESEARCH
INSTITUTE

1960-61



WEST AFRICAN COCOA RESEARCH INSTITUTE

ANNUAL REPORT 1960-61

ERRATA

P.14. Table 1

Mean Relative Humidity 23-year Mean
(1500 G.M.T.) 1960.

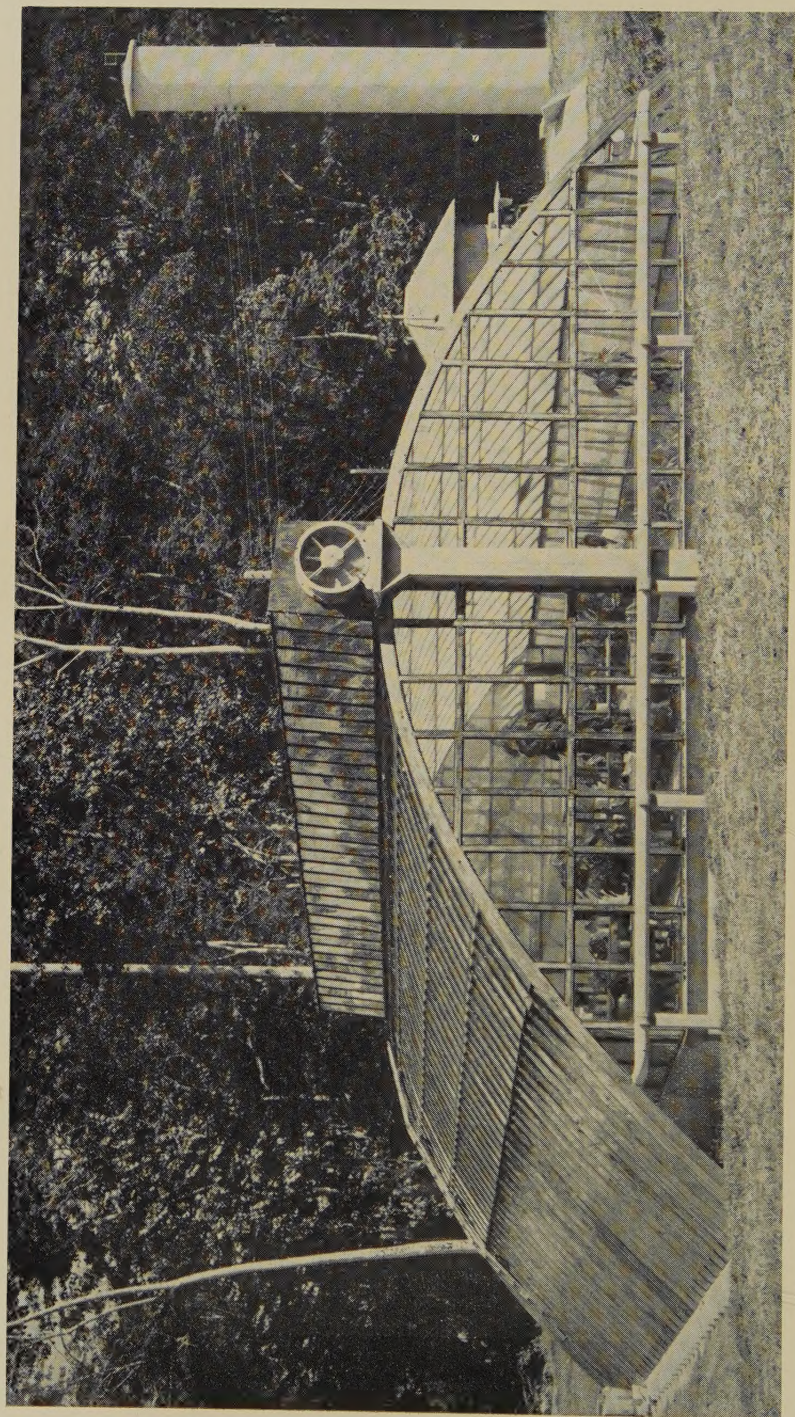
	April	May	June	July	August
<u>For</u>	59.9	64.8	70.7	70.8	69.6
<u>Read</u>	62.8	67.9	73.9	73.9	72.5

Annual rainfall (in inches) 1938 to 1960

1956 For 61.12 Read 51.12

P.65. Third paragraph, last line

For total - C Read organic C



The new glasshouse at Tafo, used by the plant physiologists for micronutrient studies, (see p. 12)

ANNUAL REPORT
of the
WEST AFRICAN
COCOA RESEARCH
INSTITUTE

1960-61

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1962

**A POISONOUS INSECTICIDAL SOLUTION
HAS BEEN USED IN BINDING THIS BOOK**

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MANAGING COMMITTEE

At 31st March 1961

CHAIRMAN

§*Administrator, West African Research Office.

MEMBERS

§*†Director, West African Cocoa Research Institute.

§*Chairman, Ghana Cocoa Marketing Board.

Y. Sefa-Boakye, Esq., Ghana.

S. E. Ntim-Kwafo, Esq., Ghana.

§*Principal Secretary, Ministry of Agriculture, Ghana.

*†Chief Cocoa Officer, Ghana.

§Permanent Secretary, Ministry of Economic Development,
Nigeria.

†Director of Agricultural Research, Federation of Nigeria.

§Permanent Secretary, Ministry of Agriculture and Natural
Resources, Western Region, Nigeria.

*†Chief Agricultural Extension Services Officer, Western Region,
Nigeria.

Rev. E. T. Latunde, O.B.E., Nigeria.

§*†Director of Agriculture, Sierra Leone.

CO-OPTED MEMBERS (non-voting)

Manager, Messrs Cadbury & Fry, Ghana.

Manager, Messrs Rowntree-Fry-Cadbury, Nigeria.

*Chief Inspector of Agriculture, Eastern Region, Nigeria.

*Principal Agricultural Officer, Southern Cameroons.

§*†Deputy Director (Nigeria), WACRI Station, Ibadan, Nigeria.

Secretary, West African Cocoa Research Institute, Ghana.

* Members of General Purposes Sub-Committee

† Members of Technical Sub-Committee

§ Members of Staff Sub-Committee

SENIOR STAFF

At 31st March 1961

TAFO STATION

DIRECTOR	J. Lamb, O.B.E., M.SC., F.R.I.C., A.I.C.T.A.
SECRETARY	A. F. Neale, M.A., F.C.C.S.
ACCOUNTANT	J. N. A. Hyde, A.C.C.S., A.A.I.A.
ENTOMOLOGISTS	*E. Dunn, B.SC. M. R. Smith, PH.D., D.I.C., F.R.E.S. K. B. Armstrong, M.A., DIP.AG.SCI., D.I.C. B. M. GERARD, PH.D., A.R.C.S., F.R.E.S.
PLANT PATHOLOGISTS	J. W. Blencowe, PH.D. A. L. Wharton, B.SC., DIP.AG.SCI., D.T.A., M.I.BIOL. A. A. F. Brunt, B.SC., M.I.BIOL. P. D. Turner, B.SC., M.SC., M.I.BIOL. A. Attafuah, M.I.BIOL.
PLANT PHYSIOLOGISTS	†R. G. Lockard, B.S.A., M.SC., PH.D. E. J. A. Asomaning, B.SC., PH.D.
PLANT BREEDER	D. R. Glendinning, B.SC.
CHEMISTS	‡R. H. Kenten, B.SC., A.R.I.C. D. K. Acquaye, B.SC., PH.D.
SPECTROGRAPHER	J. C. Burridge, M.A., B.SC.
AGRONOMISTS	T. H. R. Hall, B.SC. R. W. Smith, B.SC.
STATISTICIAN	C. de Jonge, L.I., A.R.N.S.A.S.
LABORATORY TECHNICIAN	‡A. J. H. Arnold, A.S.E.
MEDICAL OFFICER	P. K. K. Knudsen, CAND. MED. ET. CHIR., D.T.M. & H.
PLANTATION MANAGER	H. W. S. Allison
ASSISTANT PLANTATION MANAGER	E. O. Quao
GUIDE-DEMONSTRATOR	F. E. Decker
MAINTENANCE ENGINEER	G. O. Hayward, A.I.E.E.

* Seconded from East of Scotland College of Agriculture

† On Canadian Technical Assistance Scheme

‡ Seconded from Rothamsted Experimental Station

ASSISTANT	MAINTENANCE	
ENGINEER	...	G. O. Amponsah
WORKS SUPERINTENDENT	...	E. K. Berko

IBADAN STATION

DEPUTY DIRECTOR	...	T. W. Tinsley, B.SC., PH.D., M.I.BIOL.
SECRETARY ...	...	H. L. Pugh, F.C.C.S.
ENTOMOLOGISTS	...	R. G. Donald, B.SC., A.I.C.T.A., M.I.BIOL., F.R.E.S. P. F. Entwistle, B.SC., A.R.C.S., F.R.E.S.
PLANT PATHOLOGISTS	...	J. M. Thresh, B.SC., A.R.C.S. C. K. H. Martini, PH.D. D. Kay, B.SC., M.I.BIOL. E. C. Hislop, B.SC., D.P.P. J. F. Longworth, M.SC., M.I.BIOL.
CHEMIST ...	...	M. Wessel, L.I.
AGRONOMIST/STATISTICIAN...		G. H. Freeman, M.A., DIP.STAT., PH.D.
PLANTATION OFFICER	...	W. Rides

ADMINISTRATION

MANAGING COMMITTEE

Two meetings of the Managing Committee were held during the year:

30th Meeting was held on 15th September 1960 at Tafo.

31st Meeting was held on 13th February 1961 at Tafo.

STAFF

The following officers were on leave during the periods stated against their names:

Mr J. Lamb (from 23rd March 1960 to 17th August 1960 and from 22nd February 1961 on final leave).

Mr E. Dunn (from 19th April 1960 to 27th July 1960).

Dr T. W. Tinsley (from 29th November 1960 to 27th March 1961).

Dr J. W. Blencowe (from 12th July 1960 to 28th December 1960).

Mr G. O. Hayward (from 5th October 1960 to 28th February 1961).

Mr R. H. Kenten (from 24th November 1960 to 10th January 1961).

Mr A. A. F. Brunt (from 30th November 1960 to 22nd March 1961).

Mr A. F. Neale (from 22nd February 1961 to 31st March 1961).

Acting Appointments

Dr J. W. Blencowe acted as Director from 23rd March 1960 to 11th July 1960, and from 22nd February 1961 onwards.

Mr R. H. Kenten acted as Director from 12th July 1960 to 17th August 1960.

Mr R. G. Donald acted as Deputy Director (Ibadan) from 29th November 1960 to 27th March 1961.

Mr J. N. A. Hyde acted as Secretary in the absence of Mr A. F. Neale on leave, in addition to his duties as Accountant.

New Arrivals

Mr. A. F. Neal, April 1960

*Mr V. Ammah-Attoh, August 1960.

*Dr D. K. Acquaye, September 1960.

*Dr E. J. A. Asomaning, September 1960.

Dr B. M. Gerard, November 1960.

Mr M. Wessel, December 1960.

Dr G. H. Freeman, September 1960.

Mr G. O. Amponsah, formerly a Senior Technical Assistant was promoted Assistant Maintenance Engineer at Tafo on 20th December 1960.

* After completion of scholarship courses.

Transfers

Mr H. L. Pugh transferred to Ibadan Station as Secretary with effect from 29th April 1960.

Mr M. Wessel transferred to Ibadan Station on 20th March 1961.

Resignations

Mr J. Lamb went on final leave on 22nd February 1961.

Mr R. K. Cunningham went on final leave on 22nd April 1960.

Mr J. M. Thresh went on final leave on 3rd May 1960.

Dr R. G. Hurd went on final leave on 4th May 1960.

Miss D. J. Ellis went on final leave on 7th May 1960.

† Mr A. J. H. Arnold went on final leave on 30th November 1960 on completion of his secondment from the Rothamsted Experimental Station.

Mr D. Kay went on final leave on 13th July 1960.

Mr B. Ammah-Attoh, a Ghanaian Entomologist was released to enable him to take up the post of Deputy Executive Secretary, Ghana National Research Council with effect from 9th January 1961. The Managing Committee has since waived his bond.

† On completion of secondment.

CONFERENCES

Dr T. W. Tinsley and Mr D. R. Glendinning attended the 8th Inter-American Cacao Conference at Port of Spain, Trinidad, from 15th to 25th June 1960. Mr Glendinning also attended the Cocoa Breeding Seminar that preceded the Conference and visited the Inter-American Institute of Agricultural Sciences at Turrialba in Costa Rica.

J. F. Longworth, T. W. Tinsley, J. W. Blencowe, E. Dunn, A. L. Wharton and P. D. Turner attended the Commonwealth Mycological and Entomological Conferences in London.

During the year a number of the Tafo Staff visited Ibadan and several of the Ibadan Staff visited Tafo.

Dr J. W. Blencowe attended the Fourth Symposium on Virus Diseases of Fruit Trees in Europe from 25-30th July at Copenhagen, and visited Sierra Leone in January.

The Institute contributed an exhibit on cocoa research to the Federal Pavilion at the Nigerian Independence Exhibition held in Nigeria from 1st to 22nd October 1960.

An exhibit was also displayed at the West African Science Association Conference held at Ibadan in December 1960 at which Messrs Longworth and Entwistle read papers.

VISITORS

The Institute was honoured by a visit of Marshal Tito, President of Yugoslavia on 10th March 1961.

Dr Walter Carter of the Pineapple Research Station, Hawaii spent five months at the Institute from the end of September as a consultant under the sponsorship of the United States International Co-operation Administration and United States Operations Mission in Ghana. Both stations have been visited by many persons distinguished in the fields of Science, Commerce and Industry.

TAFO STATION AND PLANTATION MANAGEMENT

The clearing of 40 acres in Block C was completed; a further 6 acres in Block D and 24 acres in Block A were felled and cleared for planting in 1961. Fifteen acres of hybrid, 5 acres of Amazon, and 10 acres of Amelonado cocoa were planted in Block C under temporary tree-cassava shade. *Terminalia ivorensis* A. Chev. shade trees were planted concurrently with the cocoa. Experimental swollen-shoot-resistant varieties were planted under thinned forest shade on 2½ acres in Block E and 4 acres in Block Q (Old Station). Conditions for planting and establishment were less favourable than in the previous year and the young seedlings were adversely affected, first by water-logging, and then by drought. About 20 per cent of the plants were lost, but the remainder survived the abnormally long dry season and are making satisfactory growth.

Forest tree and ornamental nursery

Large numbers of *T. ivorensis* seedlings, required for shade trees, were grown, and small quantities of ornamental plants supplied for the laboratory and residential areas.

Seed and cutting production

A total of 83,000 F3 Upper Amazon pods were sent to Nigeria and 1,200 to Sierra Leone. In addition some 300 F2 Amazon and hand-pollinated hybrid pods were sent to Nigeria and 200 to Sierra Leone. More than 46,000 pods obtained from early mid-crop harvests, or from lots unfit for export, were sold to members of W.A.C.R.I. staff.

While the propagator was being reconditioned, only 7,500 cuttings were set and 82 per cent of these rooted successfully. Some *Theobroma angustifolia* (D.C.), *T. grandiflora* (K. Schum) and *T. bicolor* (Humb. & Bonpl.) were successfully rooted as were 60 per cent of the cuttings from young seedlings of *Bombax brevicauspe* (Sprague), but cuttings from older trees of this species failed to root.

Building construction, etc.

The glasshouse illustrated in the Frontispiece was completed during the year. It was designed by the Maintenance Engineer to satisfy the requirements of the plant physiologists for work on mineral nutrition of cocoa. The building, which was constructed by W.A.C.R.I. staff, is 72 ft. long, 34 ft. wide and 14 ft. high. The walls are 7 ft. high and the full height to the roof is unobstructed within the building. No metal is used in that part of the structure above the working area. The main structure consists of 36 laminated timber arches of parabolic form and 6 in. $\times$ 2 in. cross section, springing from concrete footing blocks at ground level and 48 ft. apart. The arches are spaced at 26 in. centres and are joined in the longitudinal direction by plywood spacers glued on edge to the side faces beneath the points of overlap of the standard 4 ft. $\times$ 2 ft. agricultural glass roofing sheets.

Longitudinal stability is provided by a reinforced concrete column at each end of the house, which also serve as supports for 30 in. 5 h.p. fans which exhaust air from the house through the 4 ft. $\times$ 4 ft. glass-covered duct above the ridge. The glasshouse is completely insect-screened.

Rainwater from the roof is collected by 6 in. tubular polyvinylchloride (PVC) guttering and discharged to an underground settling tank of some 10,000 gallons capacity. A 400-gallon water tower provides sufficient working head for the ion-exchange water purification equipment. Both tanks are of reinforced concrete and all the pipe-work is of PVC.

The installation of the mechanical cocoa drier was completed in October and it was used to dry part of the main crop (see below). The unit was manufactured by Woods of Colchester Ltd. and is essentially similar to that described by Wood (*Trop. Agriculture, Trin.*, **38**, 1, 1961). It consists of a large open drying platform of perforated aluminium sheet which can carry up to $2\frac{1}{2}$ tons wet cocoa at a depth not exceeding 6 inches. A fan forces air firstly through a diesel fuelled heat exchanger and then through the cocoa. Unlike the drier of Wood the unit is installed in a reasonably air tight building and there is provision for partial or full recirculation of the inside air. A faster flow of hot air can be put through the cocoa when recirculation is used without serious wastage of heat and this leads to quicker drying without appreciable increase in fuel consumption.

The Central Stores buildings were completed and the stores and store-keeping arrangements were reorganized. A swimming pool for the use of the senior staff was built alongside the clubhouse. This

has been a most popular addition to the social amenities at the Institute, and the staff wish to thank the Managing Committee for providing it.

Cocoa production

A total weight of 224,563 lb. of dry cocoa was produced during the year; 216,148 lb. were sold for £G11,074. Recorded data from 1,266 tray and heap-fermentations were obtained; about 24 tons of cocoa were dried in the new mechanical drier. The continued rise in cocoa production is illustrated in Figure 1.

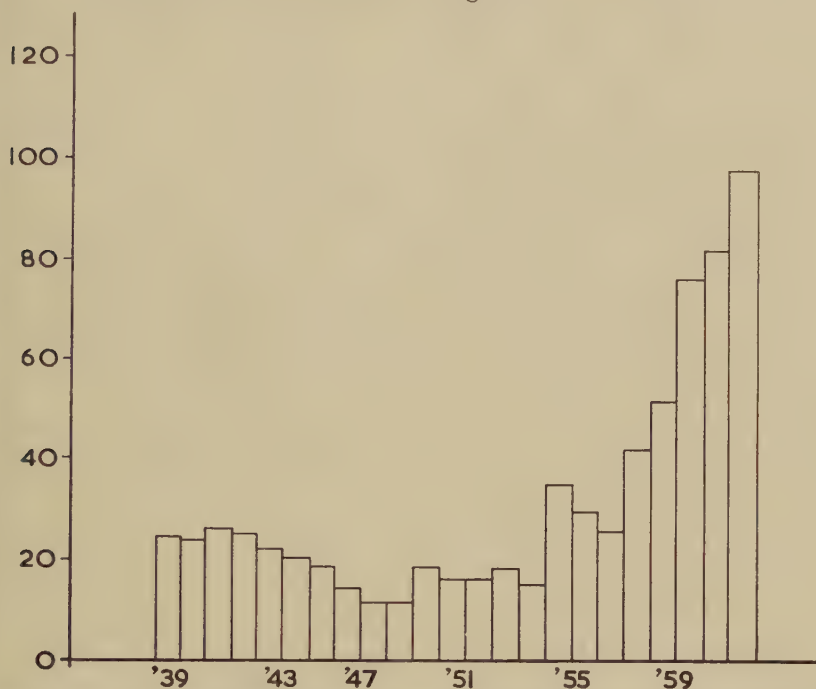


FIGURE 1. Cocoa sales chart. Tonnage of dry cocoa sold by W.A.C.R.I. by the end of each financial year (31st March).

Some three million cocoa pods were processed during the season, 8.1 per cent were discards because the beans were unfit for fermentation. The conversion factor of fresh wet beans to dry cocoa was 44.2 per cent by weight; on average, 11.8 pods yielded 1 lb. of dry cocoa.

Plots Committee

The Plots Committee has continued to meet at regular intervals. Two of the experiments planned for 1961 are designed to investigate the effect of fertilizers on young cocoa. As a result of experience

WEATHER SUMMARY—TAFO

TABLE I

Meteorological data—Tafo 1960. Figures for 1960 compared with 23 year means

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest Shade Maximum 23-year mean 1960	91.5	93.9	93.2	93.7	92.2	89.0	87.0	86.8	88.0	89.7	90.6	90.6
Lowest Shade Minimum 23-year mean 1960	59.4	62.0	66.3	66.8	67.1	66.4	65.7	65.2	67.1	67.0	66.0	62.6
Mean Relative Humidity 23-year mean 1960	61	62	68	68	69	69	62	67	68	68	68	60
Mean Relative Humidity (0000 G.M.T.) 1960	86.3	83.9	82.1	81.1	82.0	85.1	86.0	85.9	85.3	83.3	81.3	84.2
Mean Relative Humidity (1500 G.M.T.) 1960	87.1	84.5	81.1	82.8	80.7	85.0	84.5	86.4	83.5	82.7	79.4	80.7
Rainfall in inches 23-year mean 1960	56.1	53.6	57.4	59.9	64.8	70.7	70.8	69.6	71.3	71.0	66.0	61.9
Number of Wet Days 23-year mean 1960	60.1	57.5	64.0	66.9	64.5	74.5	68.6	73.1	72.2	70.1	63.6	62.5
	1.55	3.51	6.10	6.27	7.40	8.91	5.58	2.51	6.09	8.85	4.23	2.59
	2.95	3.28	6.84	10.34	1.92	16.45	1.89	4.53	9.75	11.65	1.78	5.89
	3.7	7.0	12.1	11.0	13.9	18.9	13.8	12.5	17.1	18.8	11.2	6.4
	4	8	16	15	10	20	11	14	21	18	11	9

Annual rainfall (in inches) 1938 to 1960

	1938-47 Mean	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	23-yr. Mean
61.47	66.99	71.81	63.49	66.23	65.77	53.88	57.53	73.16	61.12	70.90	68.13	77.27	63.60		

Monthly rainfall (in inches) and number of wet days, April 1960 to March 1961

Month	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March
Rainfall in inches	10.34	1.92	16.45	1.89	4.53	9.75	11.65	1.78	5.89	0.09	1.89	2.74
Number of Wet Days	15	10	20	11	14	21	18	11	9	3	2	11

WEATHER SUMMARY—GAMBARI

TABLE 2
Meteorological data—Gambari 1960

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest Shade Maximum	91	95	93	90	90	87	85	84	83	86	80	90
Lowest Shade Minimum	68	73	71	71	70	71	70	71	70	70	69	70
Mean Relative Humidity (0000 G.M.T.)	85	81	82	85	84	87	88	98	88	86	85	86
Mean Relative Humidity (1500 G.M.T.)	53	46	55	64	47	73	77	77	80	77	69	66

Monthly rainfall (in inches) and number of wet days, April 1960 to March 1961

Month	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March
Rainfall	6.40	6.67	9.54	7.37	8.58	6.31	6.76	3.03	2.56	0.24	—	2.69
Wet days	15	14	18	13	13	14	16	5	3	1	—	5

Total rainfall 1960 64.19 in.

TAFO STATION

EXPERIMENTAL AREAS

Agronomy and Chemistry

- A3-Clonal collection.
- A6-Establishment of Upper Amazon cocoa on clear-felled land.
- B1-Upper Amazon multiplication area.
- B2-Upper Amazon spacing and pruning experiment.
- C2-Upper Amazon thinning experiment.
- C4-Hybrid shade and manurial experiment.
- D7-Pruning experiment.
- E1a-Shade efficiency experiment.
- G1-Rates of application of major nutrients (NPKMg).
- G4-Comparison of experimental and commercial fertilizer mixtures.
- G5-Fertilizer; 2⁴NPKMg factorial experiment.
- H1/L2-Types of phosphate experiment.
- H5-Cover crop and mulches experiment.
- H6-Soil exposure experiment.
- J1-Amelonado spacing experiment.
- J3-Management studies on clonal cocoa.
- K1-Amelonado shade, manurial and irrigation experiment.
- K2/O1-Upper Amazon shade and manurial experiment.
- P2-Amelonado pruning experiment.
- R3-Hybrid seed garden.

Botany

- D5-9th Progeny trial area.
- D8-3rd Clonal trial.
- D9-9th Progeny trial area progenies.
- J2-Museum plot.
- K3-Museum plot.

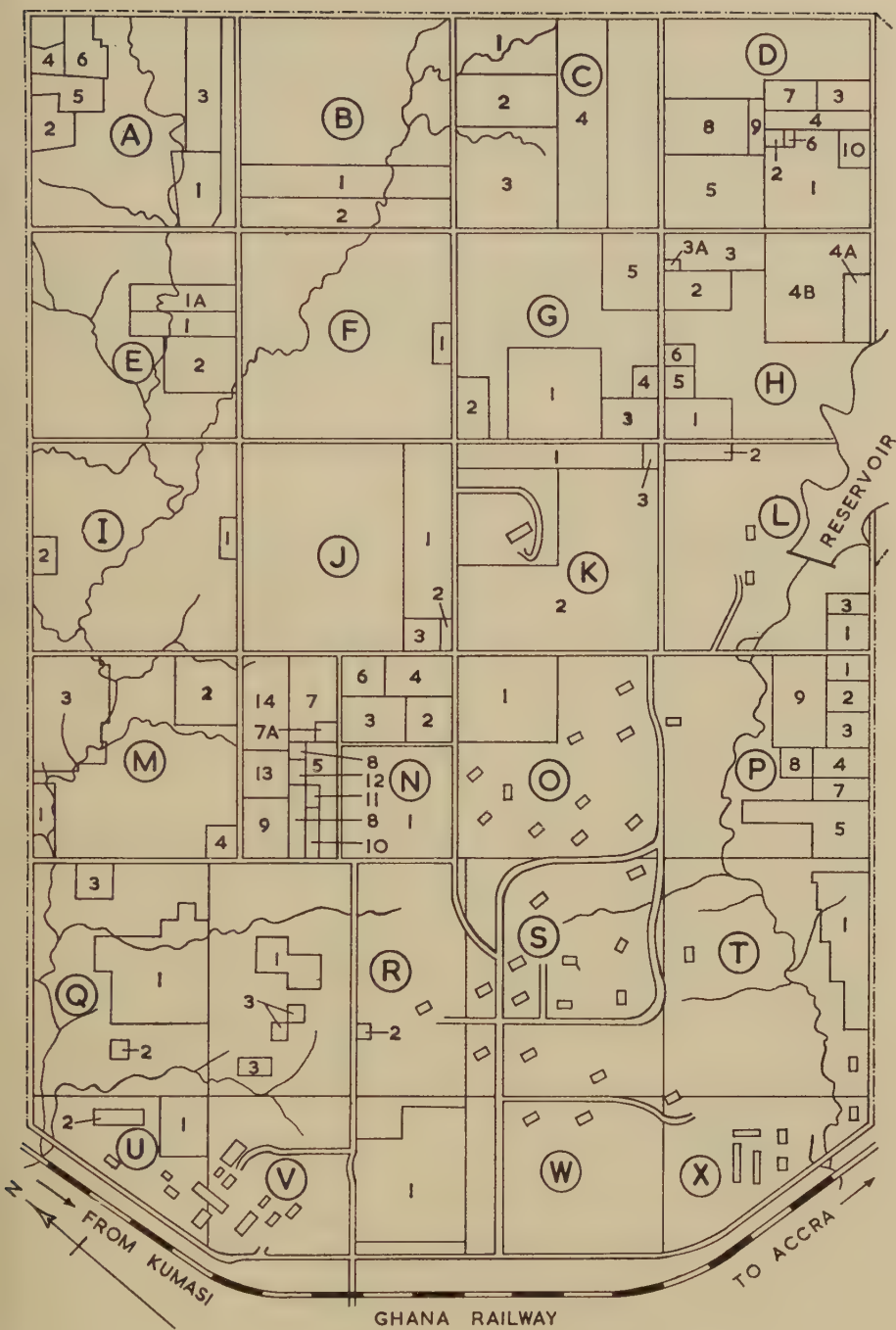
- M1-Clonal collection.
- M2-Clonal trial (Ghana selections).
- M4-Experimental plantings 1960.
- N1-Trinidad introduction area.
- N2-Species area.
- N3-Trinidad introduction area extension.
- N4-2nd Clonal trial.
- N5-Multiplication area.
- N6-Observation area including polyploid plot.
- N7-8th Progeny trial area.
- N7a-2nd Albino plot.
- N8-Columbian introductions area.
- N9-F₁, F₂ and F₃ trial.
- N10-WAE₅ plot (1958).
- N11 }
N12 } -Small experiments 1959.
N13 }
- N14-Mass planting of varieties.
- V1-1st Progeny trial area.
- U2-2nd Progeny trial area.

Pathology

- A2-Collecton of virus-tolerant trees.
- A4-Effect of cocoa virus isolates on growth and yield of Amelonado cocoa.
- E1-Virus resistance trial 1959.
- E2-Virus resistance trial 1960.
- H2/3-Effect of severe swollen shoot virus on Amelonado and Amazon cocoa.

Entomology

- A1-Mealybug experiment.
- D1-Pollination experiments.
- D6-Pollination studies.
- H4b-Ecological insect studies.



gained from the results of fertilizer experiments to date, the Committee approved the alteration of the composition of the annual fertilizer dressing applied to mature cocoa to 50 lb. N/acre as Urea, 100 lb. P_2O_5 per acre as Triple Phosphate and 40 lb. K_2O /acre as Sulphate of Potash applied in one application in April. An additional meteorological station is to be set up in an area of mature cocoa.

Records of experiments

During the year a start was made on the documentation and classification of experimental records with a view to systematic archiving. Owing to the large volume of data, it was only possible to deal with Agronomy Division and some of Chemistry Division records.

IBADAN STATION

Gambari Experimental Station

Negotiations for the acquisition of some 770 acres of the northern portion of the Gambari Forest Reserve are proceeding favourably. Responsibility for a portion of the site containing 53 acres farmed and maintained by the Ministry of Agriculture and Natural Resources, Western Region of Nigeria, was assumed by the Institute on 1st July and occupation of the remainder of the area was authorized on 31st January 1961. Building sites have been cleared, a weir has been built across the River Ona for domestic water supply, and four miles of service roads are being constructed.

Vehicles, tractors and implements have been purchased and rapid progress is being made with the clearing of land for the planting of cocoa. A nursery large enough to accommodate 120,000 cocoa seedlings is already in use.

Existing cocoa trees yielded 18,190 Upper Amazon pods that were given to the Ministry of Agriculture and Natural Resources for distribution. The yield of dry cocoa was sold for £1,034.

Mr V. O. Iweama successfully completed the course for a Diploma in Agriculture and has been appointed Assistant Technical Officer at the Experimental Station.

New house at Moor Plantation

A new house was completed at Moor Plantation in March 1961.

VIRUS RESEARCH

MECHANICAL TRANSMISSION OF COCOA VIRUSES

(A. A. F. Brunt & R. H. Kenten)

Transmission of cocoa mottle leaf virus and some isolates of the swollen shoot virus

Last year we reported the mechanical transmission of cocoa swollen shoot virus from *Adansonia digitata* L. to *A. digitata* and cocoa. The isolate used (from Kofi Pare, Eastern Region, Ghana) produces leaf symptoms as well as root and stem swellings in cocoa (*Theobroma cacao* L.) and was similar to the strain A described by Posnette (*Ann. appl. Biol.* **34**, 388-402, 1947). At least two distinct viruses, cocoa mottle leaf (CMLV) and cocoa swollen-shoot (CSSV), infect cocoa in Ghana. Isolates of CSSV produce a wide range of symptoms in West African Amelonado cocoa but other available criteria (e.g. results of cross-protection, insect transmission and host range tests) are as yet insufficient to distinguish them as separate viruses. We now report the mechanical transmission of three other virus isolates of the CSSV group which produce distinctive leaf symptoms in cocoa, do not cross-protect against strain A, and which may be distinct viruses. One isolate of the CMLV has also been transmitted mechanically.

The virus isolates used were collected in Ghana from naturally infected cocoa; the CMLV isolate was from Kpeve (Volta Region) and the CSSV isolates from Bosomuoso (Western Region), Mampong (Eastern Region) and Bosumtwé (Ashanti). Using methods similar to those previously described (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 17) all four isolates were transmitted to cocoa. Infective slurries were prepared from *A. digitata*, *Hildegardia barteri* (Mast.) Kosterm and *Theobroma bicolor* Humb. & Bonpl. infected with CMLV and from *Bombax brevicuspe* Sprague and *A. digitata* infected with the CSSV isolates (Table 3). The CMLV isolate was transmitted in seven of the fourteen experiments and the CSSV isolates in thirteen of twenty experiments.

Leaf symptoms usually appeared on the first or second flush of leaves although occasionally with the Bosomuoso isolate on the third flush. When the CSSV isolates are transmitted to cocoa half-beans by ten to fifteen mealybugs, distinct stem swellings usually appear on the seedlings in about 4-12 months. Stem swellings appeared four-six months after infection on some of the seedlings grown from beans mechanically infected with the Bosomuoso isolate and on one of those infected with the Mampong isolate. Some of the cocoa seedlings infected mechanically with the Kofi

TABLE 3
Rates of transmission of cocoa mottle leaf and swollen-shoot viruses

Virus	Source Plant	Material	Inoculum	Test Plant	Transmission rate ^a Individual Experiments	Total
Cocoa mottle leaf virus isolate from Kpeve	<i>Adansonia digitata</i>	Leaves	Slurry	<i>Theobroma cacao</i> , beans	4/37 ^b , 1/25 ^c , 1/50 ^c , 2/114 ^c , 1/53	9/279
	<i>Hildegardia harteri</i>	Leaves	Slurry	<i>T. cacao</i> , beans	0/20 ^b , 0/38 ^b , 0/25 ^b , 0/24 ^b , 0/100 ^c , 0/50	0/257
	<i>Theobroma bicolor</i>	Leaves	Slurry	<i>T. cacao</i> , beans	1/47 ^b , 1/98 ^b	1/47
	<i>A. digitata</i>	Cotyledons	Sucrose concentration	<i>A. digitata</i> , cotyledons	0/30 ^b	1/98
					1/33	0/30
Cocoa swollen shoot virus isolate from Bosumuoso	<i>Bombax brevicuspe</i>	Leaves	Slurry	<i>T. cacao</i> , beans	85/192, 3/98, 2/94, 3/100, 4/96, 4/61, 4/55, 11/100	116/796
					0/91, 0/188, 0/100	0/379
Cocoa swollen shoot virus isolate from Mampong	<i>A. digitata</i>	Cotyledons	Slurry	<i>T. cacao</i> , beans	1/20 ^b	1/20
	<i>A. digitata</i>	Cotyledons	Sucrose concentration	<i>A. digitata</i> , cotyledons	1/11	1/11 ^d
	<i>B. brevicuspe</i>	Leaves	Slurry	<i>T. cacao</i> , beans	1/224, 2/172, 1/145	4/541
Cocoa swollen shoot virus isolate from Bosumtwe	<i>B. brevicuspe</i>	Leaves	Slurry	<i>T. cacao</i> , beans	1/142 0/88, 0/82, 0/150, 0/204	1/142
						0/524

^aNumerator indicates the number of infected plants and the denominator the number of test plants inoculated.

^bIn these experiments the infiltrating solution (pH 8.0) contained 0.067 M phosphate, 0.05 M ethylenediamine tetraacetate and 0.01 M cysteine.

^cIn these experiments the infiltrating solution (pH 8.5) contained 0.1 M phosphate and 0.1 M cysteine. In the other experiments the infiltrating solution (pH 8.5) contained 0.1 M phosphate and 0.1 M thioglycolic acid.

^dThe infections were confirmed by insect transmission to cocoa.

Pare isolate and those in which virus was recovered by insect transmission from mechanically infected *A. digitata*, have now developed stem swellings.

The CMLV and the Mampong isolate of CSSV have also been transmitted from infected to healthy *A. digitata* but only after concentration of the clarified extracts by dialysis against concentrated sucrose solution (*Virology*, **12**, 328-330, 1960).

With the exception of one experiment with the Bosomuoso isolate where 43 per cent of the inoculated plants became infected the transmission rates remained low and are of the same order as those previously obtained (*loc. cit.*). However, the results are consistent and there have been no cross infections with the four viruses studied or any infections among the several thousand un-inoculated half-beans planted as controls. Moreover, it is safe to assume that conditions in the regularly-fumigated and insect-proof screen houses are adequate to prevent the occurrence of accidental infections.

Transmissions of the Kofi Pare isolate of the swollen shoot virus.

Transmissions from hosts other than cocoa. Eleven susceptible species have been tested in the hope of finding more suitable source plants than those previously studied. A low rate of transmission to cocoa has been obtained from five (Table 4); the isolate has been transmitted to *A. digitata* only from *A. digitata* and *H. barteri*.

TABLE 4

Rates of mechanical transmission of cocoa swollen-shoot virus from some hosts

Host	Transmission rates ^a	
	Cocoa half-beans	<i>Adansonia digitata</i> [†]
<i>Adansonia digitata</i>		
Cotyledons	7/237 ^b , 0/100 ^b	7/35 ^e , 0/16 ^e , 1/7 ^e
Leaves	5/94 ^b , 12/350, 0/2250, 10/121 ^c , 0/217 ^c	
<i>Bombax brevicauspe</i>	4/156 ^c , 51/621, 0 ^c 711	1/5
<i>Theobroma cacao</i>	6/600, 0/800, 4/235 ^d , 0/60 ^d	0/30
<i>Theobroma bicolor</i>	1/183 ^c , 0/94 ^c , 0/137	0/30
<i>Hildegardia barteri</i>	1/17 ^e , 0/143	1/6
<i>Corchorus tridens</i>	1/100, 0/400	0/30
<i>Sterculia alata</i>	2/78	

^aThe numerator indicates the number of infected plants and the denominator the number of test plants inoculated.

^bIn these experiments the infiltrating solution (pH 8.0) contained 0.067 M phosphate, 0.05 M ethylenediamine tetraacetate and 0.01 M cysteine.

^cIn these experiments the infiltrating solution (pH 8.5) contained 0.1 M phosphate and 0.1 M cysteine.

^dIn these experiments the infiltrating solution (pH 8.5) contained 0.1 M phosphate and 0.1 M sulphide. In the other experiments the infiltrating solution (pH 8.5) contained 0.1 M phosphate and 0.1 M thioglycolic acid.

^eClarified sap concentrated by ultra-filtration or by dialysis against concentrated sucrose solution.

[†]Infections confirmed by insect transmission to cocoa.

With the exception of *A. digitata* and cocoa and a single transmission with *H. barteri* attempts to transmit from infected to healthy plants of the same species were unsuccessful.

Attempted concentration by salt and solvent precipitation: No infectivity could be detected in precipitates separated from extracts of cocoa and *A. digitata* by the addition of alcohol, acetone or ammonium sulphate.

Preparation of inocula: Transmissions have been obtained using thioglycollate, hydro-sulphide and ascorbate in place of cysteine in the extracting solution. However, it is not yet clear whether these other reducing agents are more efficient than cysteine. These studies are continuing.

THE EFFECT OF VIRUSES ON GROWTH AND YIELD OF COCOA

(J. W. Blencowe and A. A. F. Brunt)

In experiment H2/3 (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 17) all the graft-inoculated Amelonado trees showed symptoms of infection within 20 months; by contrast, only 80 per cent of the Amazon trees had produced symptoms within two years of graft-inoculation. In experiment A4 all trees graft-infected with the virulent viruses produced symptoms within 2 years although swellings have not yet been detected on 4 per cent of the trees infected with the mild Worawora isolate.

The yields, expressed as grams of dry cocoa per tree, for the 2 years for experiment A4 are shown in Table 5. The main crop for the year 1959-60 had already set before symptoms started to appear on infected trees and it is reasonable to assume that infection did not reduce yield in that year. The 1959-60 crop data have been used as 'pre-treatment yields' and an analysis of covariance showed that in the second year after infection the Kpeve isolate had reduced yield by 64 per cent, the New Juaben by 44 per cent, the Dawa by 31 per cent and the Bosomuoso isolate by 19 per cent. The Worawora isolate had no significant effect on yield. In Experiment H2/3 the New Juaben isolate greatly reduced the yield of fertilized and

TABLE 5
Experiment A4. Yield (in grams dry cocoa per tree)

<i>Virus Source</i>	1959-60	1960-61
Bosomuoso	384	561
Dawa	371	468
Kpeve	426	262
New Juaben	413	395
Worawora	596	914
Healthy Control	320±81.1	657±72.1
<i>Mean</i>	418±33.1	542±29.4

TABLE 6
Experiment H₂/3. Yield (in grams dry cocoa per tree) for 1959-60 and 1960-61

	Amazon				Amelonado			
	1959-60		1960-61		1959-60		1960-61	
	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded	Unshaded	Shaded
Control	815	285	1321	449	690	405	954	456
Fertilizer	841	356	1375	523	1,030	456	1,262	509
Virus	658	349	908	309	680	235	174	105
Fertilizer and virus	1,056	390	1,346	545	775	270	187	89

unfertilized Amelonado trees on both shaded and unshaded plots (Table 6). On Amazon cocoa the overall responses to virus infection and applications of fertilizer are not statistically significant. However, there appears to be an interaction between these two factors and virus-infection caused a yield reduction of about 30 per cent when the trees received no additional fertilizers. Six different Amazon types are represented in this experiment; type T17 has been least damaged by virus infection.

Complete control of capsids was achieved by spraying both experimental areas with *gamma*-BHC in June, July, November and December at the rate of 2 oz. insecticide per acre. In these experiments the condition of tree canopies has been assessed at quarterly intervals by the same observer. A simple scoring system, in which a score of 5 denotes a very good canopy and lower scores various degrees of canopy deterioration, has been used to record these observations. The deterioration of the canopy of Amelonado trees infected with the severe viruses in experiment A4 has continued (Table 7) and 4 per cent of the trees have died. The canopies of the infected Amazon trees in experiment H2/3 have been slightly

TABLE 7

Experiment A4. Scores for mean canopy assessments during the second year of infection

<i>Virus Source</i>	<i>June 1960</i>	<i>Sept. 1960</i>	<i>Dec. 1960</i>	<i>March 1961</i>
Dawa	4.7	4.6	4.4	4.3
Bosomuoso	4.8	4.7	4.5	4.4
New Juaben	4.3	4.0	3.7	3.2
Worawora	5.0	4.9	4.9	5.0
Kpeve	4.5	4.3	4.1	3.6
Healthy Control	5.0	5.0	5.0	5.0

Score: 1. Tree moribund and almost leafless, but trunk not yet dead.

2. Small groups of leaves remaining on tree.

3. Considerable defoliation on major and minor branches.

4. Defoliation of some minor branches.

5. Complete canopy.

affected but, as in experiment A4, those of Amelonado trees have continued to deteriorate (Table 8).

The sprayed plots of the 28 units in the joint W.A.C.R.I./Division of Agriculture experiments continued to receive monthly applications of *gamma*-BHC at the rate of 2 oz. insecticide per acre. Using the same scoring method used in Experiments A4 and H2/3, it has been found that the canopies of infected trees in both sprayed and unsprayed plots have continued to deteriorate. Although the rate of deterioration has been a little slower in the sprayed plots

TABLE 8
Experiment H₂/3. Mean canopy assessments

	Amelonado				Amazon			
	Healthy	Shaded Virus	Virus and fertilizer	Healthy	Unshaded Virus	Healthy	Virus and fertilizer	Unshaded Virus
June 1960	4.9	3.1	3.1	5.0	3.5	5.0	3.7	4.9
Sept. 1960	5.0	2.9	2.8	5.0	3.0	5.0	3.0	4.8
Dec. 1960	4.9	2.6	2.6	4.9	2.5	5.0	2.6	4.6
March 1961	5.0	2.1	2.0	5.0	1.9	5.0	2.3	4.2

in 20 of the 28 units, it is apparent that elimination of capsids has so far not prevented the gradual decline of virus-infected trees. The yield data collected from these experiments is now being analysed.

RESISTANCE AND TOLERANCE (J. W. Blencowe and A. A. F. Brunt)

The seedlings in the variety trial E1 (*Rep. W. Afr. Cocoa Res. Inst.*, 1958-59, p. 18) have made very good growth during the past year but, as a continuous canopy has not yet formed, infection of the Amelonado guard rows has been postponed.

The planting of another variety trial (E2) was completed in July 1960. The seedlings planted were progenies of crosses expected to produce virus-tolerant trees. They have been closely planted and some of the selections will be graft-infected with a severe virus during the coming year. The tolerance of the progeny will be assessed by comparing the growth of healthy and virus-infected seedlings.

BLACK-POD DISEASE

SPRAYING TRIALS AGAINST *PHYTOPHTHORA PALMIVORA* BUTL.

Joint trial-W.A.C.R.I./Ministry of Agriculture (A. L. Wharton)

The results of a survey to determine the importance of black-pod disease in Ghana, using 5 years' data from the Ministry of Agriculture 'Capsid Yield Recorded Units', were given in the *Rep. W. Afr. Cocoa Res. Inst.* 1959-60, pp. 24-29 and in the *Proc. Sixth Commonw. Mycol. Conf.* 1960, pp. 139-147. From this data it became possible to lay out, for the first time in Ghana, an extensive fungicide control trial on farmers' cocoa for which detailed pre-treatment records were available. An additional advantage was that plots were available which could be expected to give the minimum requirements below which spraying would be uneconomic; these requirements were a potential yield of 450 lb. dry cocoa per acre and subject to a pod disease incidence of 20 per cent of the total pods harvested. Sixteen of the 23 recorded units, 7 in the Eastern Region and 9 in Ashanti, were within these limits. Each unit contained two recorded plots originally allocated to capsid control treatments but which since 1959 have both received standard Gammalin treatments. Two 'black-pod' control treatments were applied; Perenox was applied by powered, knapsack machines at a concentration of 1.6 per cent w/w and a rate of 10 gallons per acre, according to two different schedules. Plots receiving treatment A were sprayed six times at fortnightly intervals, starting at the end of April 1960 and

continuing through the first disease outbreak during the period when most of the fruits on the trees were immature. Treatment B consisted of 10 sprays at 3-weekly intervals from April to November. Treatments A or B were allocated at random to one of the two plots on each of the 16 units. The second plot at each site served as an un-treated control (C). This design allowed 8 replicates of each spray treatment, with a control plot at each site. The trial was designed to run for two seasons to allow the results to be corrected by pre-treatment data following the system devised for fertilizer experiments on mature, farmers' cocoa by Cunningham and BurrIDGE (*J. hort. Sci.* 1959, **34**, 229-237). Results from an interim analysis of the first (1960) season's results, corrected by three years' pre-treatment data, are given in Table 9. Incidence of the disease is represented by the numbers of black pods as a percentage of total pods (excluding rodent-damaged pods). Actual losses from black-pod disease were arrived at by excluding the 44 per cent of diseased, ripe pods which contain usable beans (see page 36). Differences between the two Perenox treatments were not significant but both had a significant effect on levels of black-pod disease, compared with the control. Control on the Eastern Region Units was excellent but the results from Ashanti were disappointing. It is hoped that further training of the Ashanti spraying teams, who are working in the difficult conditions of randomly-planted cocoa, will raise the efficiency of disease control.

TABLE 9
Perenox spraying trial-1960 data

<i>Treatment</i>	<i>Total pods per acre</i>	<i>Percentage 'black-pod'</i>	
		<i>Incidence</i>	<i>Loss</i>
A	9,909	19.7**	13.7*
B	11,036*	16.7***	10.6***
C	9,559	27.8	18.8

Significant differences compared with control *, **, *** represent $P=0.5$, 0.1 and 0.01 respectively.

Table 9 also shows the mean numbers of total pods per acre harvested during the 1960/61 crop season. The difference in total pods between the two Perenox treatments is not significant but the positive difference between treatment B and control is ($P=0.05$). It represents a substantial increase in yield of 15.5 per cent over the control. Even though the treatment data has been corrected for pre-treatment differences in yield over the 3 seasons 1957 to 1959 the effect must be accepted with reserve until data from a second year of Perenox treatments are collected.

Use of mineral oil (P. D. Turner)

An experiment on the Upper Amazon Spacing and Pruning Trial spraying light mineral oil at three-weekly intervals at a rate of 1 gal./acre against black-pod disease, has been continued for a second year, (cf. *Rep. W. Afr. Cocoa Res. Inst.* 1959-60, p. 29). Data for the experimental period March-October 1960 are summarized in Table 10. As in the previous year, levels of disease were lower in the sprayed plots than in the control, but disease incidence was low over the whole area. The results are awaiting statistical analysis.

TABLE 10
Disease control by mineral oil: incidence of black-pod disease

Spacing	Replicate number	Total pods	No. of black pods	% black pod	
8 × 8	3	3,200	206	6.4	Treated
8 × 8 P	2	1,815	110	6.1	
10 × 10	1	872	49	5.6	
10 × 10 P	4	3,744	114	3.0	
12 × 12	2	2,322	90	3.9	
12 × 12 P	3	2,404	76	3.2	
Total	15	14,357	645	4.5	
8 × 8	2	2,306	205	8.9	Control
8 × 8 P	3	2,640	228	8.6	
10 × 10	4	3,987	325	8.2	
10 × 10 P	1	1,649	171	10.4	
12 × 12	3	3,681	240	6.5	
12 × 12 P	2	2,212	26	1.2	
Total	15	16,475	1,195	7.3	

P = pruned to first jorquette.

RESISTANCE AND TOLERANCE

Field investigations (A. L. Wharton)

Half the resistance trial on a 5-acre site at Mpraeso (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 24) was planted in June 1960 under the supervision of T. H. R. Hall. This planting included progeny from crosses with parents resistant to black-pod disease selected from the 1st Clonal Trial. Crosses with resistant parents from the 2nd Clonal Trial were made during 1960 and the seedling progeny are ready for planting in the remaining half of the trial in June 1961. The complete trial is a randomized block of 19 selections replicated 8 times. Each plot contains 10 stands planted at a 10-ft. spacing on the equilateral triangle (3:4:3 trees per plot). Each plot is surrounded by a guard row of selfed progeny of the disease susceptible clone A12. These rows together with the triangular planting should induce a high and uniform incidence of black-pod disease over the

whole area. The final choice of selection is given in Table 11. Selections C, E and J are substitutes, from seedling stocks already available, for three crosses chosen originally and which were later excluded because they proved incompatible (U6 selfed and Na32 $\times$ ACu85) or produced insufficient seedlings (A12 $\times$ Na32).

TABLE 11

Progeny included in black-spot disease resistance trial—Mpraeso

Selection	Code letter	Parent type T = <i>Trinitario</i> Am = <i>Amelonado</i> Az = <i>Amazon</i>	Parental characteristic Resistant—R Susceptible—S
D70 $\times$ S27	A	T $\times$ T	R $\times$ R
S27 selfed	B	T	R
P30 $\times$ K5	C	Am $\times$ T	R? $\times$ R
D70 $\times$ Na32	D	T $\times$ Az	R $\times$ S
P30 $\times$ ACu85	E	Am $\times$ T	R? $\times$ R
Amelonado (Unselected)	F	Am	S
K5 selfed	G	T	R
Na32 $\times$ S27	H	Az $\times$ T	S $\times$ R
K5 $\times$ Y44	J	T $\times$ T	R $\times$ R
P30 selfed	K	Am	R?
ACu85 $\times$ A12	L	T $\times$ T	R $\times$ S
Lafi 7 ^a	M	T	R
D70 $\times$ A12	N	T $\times$ T	R $\times$ S
ACu85 $\times$ S27	P	T $\times$ T	R $\times$ R
D70 selfed	R	T	R
ACu85 $\times$ Y44	S	T $\times$ T	R $\times$ R
D70 $\times$ ACu85	T	T $\times$ T	R $\times$ R
ACu85 $\times$ K5	V	T $\times$ T	R $\times$ R
Y44 selfed	W	T	R
12B ^b	X	T	R
A12 selfed (Guard Rows)	Y	T	S

^a Buddings of clone Lafi 7 reported to be highly resistant in Samoa. (Leaf infection by *P. palmivora* already recorded in Ghana).

^b Buddings of clone 12B reported to 'escape' infection in Cameroun by character of late bearing.

Laboratory studies (P. D. Turner)

Records of the incidence of *Phytophthora palmivora* Butl. pod-infections on all the selections in the 1st and 2nd Clonal Trials have shown a number of selections to possess either a high 'susceptibility' or a degree of 'resistance' to the disease, the range of disease incidence being from 6–60 per cent (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 26; 1959–60, p. 24). The basis of this differential susceptibility has not been determined, and a research programme has commenced to elucidate the factor or factors concerned. The proposed programme covers all aspects of the disease from the time that infective spores first come into contact with the pod to the stage when the pod itself is behaving as a source of inoculum. The aim of the investigation is to provide an accurate laboratory method for testing potential disease-resistant cocoa selections.

In an experiment to examine resistance to lesion development following infection, replicates of 10 unripe pods of all selections from both trials were wound-inoculated with *P. palmivora* in the field, and detached pods were also incubated in humid chambers in the laboratory. Further replicates of ripe pods were similarly inoculated. Lesion dimensions were measured after 4 days, and the data analysed. Limited correlation was found between selections showing a low incidence of disease and a lower rate of lesion development. It was evident from the results, however, that post-penetration resistance is not the only factor involved. The results also suggested that a change in susceptibility may occur with increasing age, and that tests on detached pods may give less reliable indications of resistance than field tests.

In a preliminary experiment, extracts of external and internal endocarp tissue of single pods showing resistance in the field or laboratory and others showing a high susceptibility were bio-assayed on spore suspensions of *P. palmivora*. Extracts of unselected Amelonado pods were also included for standard comparison. Epidermal tissues of a standard depth were removed by a commercial peeler, and care was taken to exclude mesocarp from the internal endocarp tissue slices. The pieces of tissue were soaked overnight in watch glasses, the tissues then removed, and sporangial suspensions obtained from pods added to the extracts. A control suspension was added to de-ionized water. The solutions were then transferred to a cooler temperature to promote and accelerate sporangial germination. After 3 hours further development was stopped by addition of mercuric chloride solution, and measurements made of percentage germination of sporangia and zoospore and of mean length of 20 zoospore germ tubes.

Of the 'resistant' selections, complete inhibition of zoospore germination was found with extracts from unripe pods of ACu85, D71 and P30, and these extracts also severely inhibited germination of sporangia. Marked zoospore inhibition (LD75) was also found with unripe pods of N38, D70 and U6, and with the ripe pod of S27. Other 'resistant' selections gave only low inhibitory rates. On average, germination of sporangia in epidermal extracts of unripe pods of 'resistant' types was 69 per cent of the control, zoospore germination 24 per cent and germ tube length 67 per cent; mean values for ripe pod extracts were 104, 47 and 103 per cent respectively. Epidermal extracts of unripe pods of 'susceptible' selections showed values which were on average, approximately double those of 'resistant' selections. However, marked inhibition (LD75) of zoospore germination was found with the epidermal extracts of unripe pods of O2, R15, and of ripe pods A62, O2, R15 and W41.

Mean germination of sporangia in epidermal extracts of unripe pods of 'susceptible' types was 91 per cent of the control, zoospores germination 52 per cent, and germ tube length 119 per cent; mean values of ripe pod extracts were 92, 56 and 102 per cent respectively.

Extracts of the internal endocarp tissue of some 'resistant' selections also showed inhibition of zoospore germination, although no extract produced complete inhibition. Marked inhibition (LD75) was shown by extracts of unripe pods of B1, D70 and ACu85, and of ripe pods of B1, D70, D71 and P30. On average, germination of sporangia in extracts of unripe pods of 'resistant' types was 104 per cent of the control, zoospore germination 47 per cent and germ tube length 103 per cent; mean values for ripe pod extracts were, respectively, 96, 36 and 95 per cent. Occasional inhibition of zoospore germination was also found with internal tissue extracts of 'susceptible' selections, with ripe tissues of A73 and W41, and of the unripe pod of A12, showing most marked inhibition. Mean values for the extracts of 'susceptible' selections were 89, 81 and 118 per cent of the control for sporangial germination, zoospore germination and germ tube length respectively for unripe internal endocarp tissue, and 100, 62 and 135 per cent for tissue from ripe pods. It was apparent from the range of values obtained that the ability to inhibit spore germination and subsequent development varied considerably, both between selections and between different tissues of a single pod. Further investigations are in progress.

In further tests with unselected Amelonado pods, aqueous extracts of mesocarp tissue showed very high inhibitory properties on addition of spore suspensions, suggesting that this tissue forms both a physical and chemical barrier to bean infection. In addition, bean pulp of both ripe and unripe pods were found to inhibit completely germination of both sporangia and zoospores.

Measurements were also made of the pH, water content and percentage dry weight of external and internal endocarp tissues from each selection used in the tissue extract spore tests, and analyses of the total nitrogen content of the same tissues were made by the Chemistry Division. No significant differences were found between the two groups of selections.

A survey is in progress of polyphenol and polyphenoloxidase activity of 'resistant' and 'susceptible' selections, comparing these with unselected Amelonado controls. Acetone powders of the enzyme have been prepared from cherelles and internal and external endocarp tissues of a number of selections by slicing the tissue directly into 80 ml. of acetone, macerating for 1 min., and washing four times in 40 ml. of acetone with a final wash in 40 ml. of ether.

The air-dried powders were then finely ground in a mill and stored at approx. 6°C. The enzyme activity of 10 mg. of each powder was tested by addition to 25 mg. of pyrogallol per 10 ml. M/10 citric acid buffer at pH 6.0. After 10, 20, 30 and 40 min., 10 ml. of the bulk solution were removed, the reaction stopped with HCl, and the solution centrifuged to remove suspended mucilage and particles. The supernatant was then tested colorimetrically with an EEL absorptiometer using filter 601. From these readings rates of enzyme activity were calculated. The results from some selections, summarized in Table 12 showed a wide variation in enzyme activity of powders between different selections, particularly between older tissues, and that significant differences are found between enzyme activity of external and internal tissue extracts of the same pods in a number of selections. Work continues on this investigation.

TABLE 12

Polyphenoloxidase activity of acetone powders, from ten pods of each selection, expressed as the mean time taken (min.) to reach an optical density increase of 15 with filter 601

Selection	Cherelle tissues	Immature endocarp tissues	
		External	Internal
A12	18	20	28
ACu85	11	26	30
B1	19	34	37
D70	15	18	24
O2	22	26	34
P30	16	31	32
R15	17	29	32
U6	20	21	24
Unselected			
Amelonado	17	17	18

ALTERNATE HOSTS OF FUNGAL PATHOGENS (P. D. Turner)

A further selection of diseased plants have been tested for natural infection by *P. palmivora* (Rep. W. Afr. Cocoa Res. Inst., 1958-59, p. 24). These were *Blighia welwitschii* (Hiern) Radlk., *Capsicum annum* Linn., *Culcasia scandens* P. Beauv., *Marantochloa inaequilatera* Hutch, *Millettia zechiana* Harms., *Randia* (?) sp., *Rauwolfia vomitoria* Afz., *Vitex grandifolia* Gurke and a fern. *P. palmivora* could not be isolated from any host. Two species of *Mimusops*, *M. elengi* Linn. and *M. commersonii* Engl., were found to have fruits heavily infected with *Trachysphaera fructigena* Tabor & Bunting, and are new host records for the fungus in Ghana.

A GALL DISEASE OF COCOA IN GHANA

(A. A. F. Brunt and A. L. Wharton)

Final results from a survey to determine the occurrence and distribution of the gall disease of cocoa in Ghana (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 30) are given in Table 13.

TABLE 13

Distribution of gall-bearing trees found in Ghana from August 1958 to August 1960

Region	Locality	Number of trees	
		Amelonado	Amazon
Eastern	Adidiso	1	—
	Adonkwanta	1 ^a	—
	Kofi Pare	1	—
	Maase	20 ^b	—
	Nankese	5 ^a	—
	Nkawkaw	1	—
	Oworam	1	—
	Tafo	7 ^{b, c, d}	1 (T72)
Ashanti	Ankasi	1	—
	Goaso	3	—
	Tepa	3	—
	Wiowso	8	—
Western	Assin Foso	—	1 (T63)
	Assin Prasu	1	—
	Wiawso	—	2 (T62)
Total	15	53	4

^a, ^b, ^c includes one tree bearing 2, 3 and 4 galls respectively.

^d includes two trees bearing 2 galls.

Following the failure to isolate an infective bacterium from galls (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, pp. 30-34) attention was re-directed to finding a fungal pathogen. The disease is now known to be caused by a strain of *Calonectria rigidiuscula* (Berk. & Br.) Sacc.

The fungus has been recovered, with difficulty, from three galls on trees and from four galls produced on seedlings after inoculation of half-beans with macerated tree-gall tissue, (Brunt and Wharton, *Nature, Lond.*, 187, 80-81, 1960; Brunt and Wharton, *Proc. Sixth Commonw. mycol. Conf.*, 1960, 148-156). Pure cultures of each isolate have induced galls on cocoa seedlings grown from inoculated half-beans (Table 14).

The fungus has been recovered from two of these galls and one re-isolate (B75 (a) in Table 14) again shown to be pathogenic by infection tests on half-beans. Three galls are developing on pod stalks and flower cushions of trees after injecting spore suspensions of

isolate number B151. Small galls were formed on *Vigna sinensis* (Linn.) Savi ex Hassk., when isolate B75 was wound-inoculated into buds of seedlings. Aqueous extracts of these galls inoculated to cocoa half-beans produced galls on the seedlings from which pathogenic cultures of the fungus (B75^a in Table 14) were recovered.

TABLE 14
Infectivity of C. rigidiuscula isolated from galls

Isolate	Origin	Transmissions from separate tests	Total transmissions
B84	Tree gall	4/5 3/4 4/5	11/14
B86	Tree gall	5/5 3/5 4/5	12/15
B87	Tree gall	4/5 2/4 4/5	10/14
B75	Seedling gall	5/5 5/5 5/5 5/5 5/5 10/10 5/5 10/10	55/55
B75 ^a	Seedling gall	2/3 4/4 9/10 5/5 4/5 4/5 5/5 3/4 5/5 3/4 4/5	48/55
B85	Seedling gall	4/4	4/4
B151	Seedling gall	4/4 5/5 10/10 5/10 5/5 10/10 10/10 7/9 10/10 4/6 10/10 10/10 5/8 6/9	101/116
B151 ^b	Seedling gall	5/5 6/9 5/5 15/18 10/10 5/5 5/5 5/5	56/62
B157	Seedling gall	9/10 4/5	13/15
Total			310/350

Numerator indicates the number of infected plants and the denominator the number of test beans inoculated.

^a Data from 2 re-isolates.

^b Data from 3 single spore sub-cultures.

Table 14 shows the high infectivity of all these isolates to beans of West African Amelonado cocoa. The table incorporates results from a number of transmission experiments in which aqueous suspensions of conidia and the mycelium of the isolates were applied to half-beans with sterile, artists' paint brushes soaked in the inoculum. The brushes were always tested for sterility by first brushing 5-10 control half-beans with sterile water; galls never developed on the control seedlings which were grown alongside treated beans in the same seed boxes.

C. rigidiuscula sporulates profusely from gall tissue which is surface sterilized and then placed in sterile humid chambers. Even washings collected from fresh, untreated galls, after spraying them with a fine mist of water, contain dense suspensions of spores. The washings are highly infectious in tests on cocoa half-beans. There is little need to simplify the technique, of applying the inocula to cocoa half-beans with a sterile brush, but it is now known that simply dipping half-beans in inocula is equally effective, and that the two methods work almost as well when applied to whole beans.

In Ghana *C. rigidiuscula* is commonly found infecting debilitated cocoa. Two cultures of the fungus isolated from such material on trees free from galls did not cause gall formation in any of 120 seedlings inoculated as beans. These cultures and two of the gall isolates (B75 and B151) sent to the Commonwealth Mycological Institute have been identified by Dr C. Booth as *C. rigidiuscula* but it is not yet known to what extent cultures from the two sources differ.

MINISTRY OF AGRICULTURE CAPSID YIELD-RECORDED UNITS—YIELD TRENDS SINCE 1954 (A. L. Wharton)

An interest was retained in yield trends on all the 23 'Capsid Yield-Recorded Units' of the Ministry of Agriculture since the records were last analysed in 1959 (cf. section 'black-pod disease; spraying trials'). A summary is given here incorporating the yield records for 1959 and 1960 which were not previously available.

In extracting the data, potential crop (total pods harvested) is represented by the summation of the three categories of pods, 'Healthy Ripe', 'Diseased Ripe' and 'Diseased Unripe'. Records for 'Immature Ripe' pods were excluded because these are large fruits (over 3 inches in length) lost from physiological wilt and do not represent potential crop. Similarly, figures for pods destroyed by rodents were also excluded as potential crop. Losses from rodents from 1954 to 1960 have been negligible (Table 15) and it is unlikely that they will ever be considered sufficient to warrant control measures.

TABLE 15
Rodent damaged pods as a percentage of total pods

	1954	1955	1956	1957	1958	1959	1960	7-year Average
Eastern region	2.1	2.1	1.8	2.2	4.5	2.9	2.8	2.7
Ashanti region	1.3	2.1	2.5	1.9	2.6	1.4	1.4	1.9

Figure 2 shows the potential yield (where 12 pods = 1 lb. dry cocoa) for each of the years 1954 to 1960 from all the plots of the 11 Eastern Region and 12 Ashanti Units which have been sprayed against capsids from their initiation. In Figure 2 the average annual yields for all the 23 plots (Ashanti and Eastern Region) shows the radical change since the end of 1958, when the data was last summarized. At this time it was considered that yields had virtually reached their maximum in 1956 and that the variations in crop over the subsequent three years (1956-1958) represented seasonal variations. However, with the 1959 and 1960 data it now appears

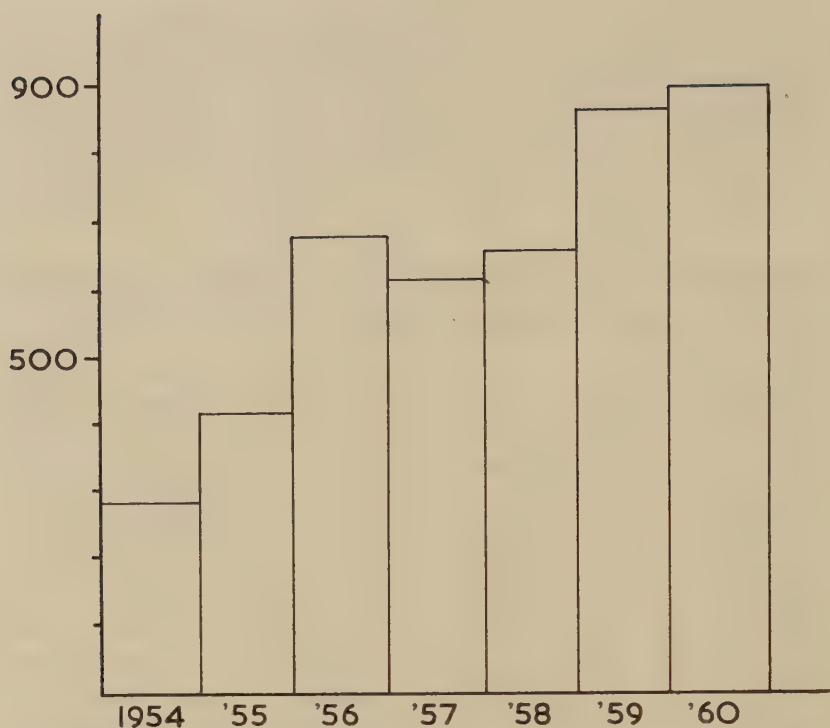


FIGURE 2. Potential yield in lb. per acre of dry cocoa from capsid-sprayed plots in the Ministry of Agriculture 'capsid-yield-recorded units'. (Assumed conversion rate, 12 pods equivalent to 1 lb. dry cocoa.)

that capsid control exerts a long-term effect which is still being felt after 7 years. Whether or not the increases in Figure 2 are approximately linear is difficult to say. There are bound to be considerable seasonal variations in crop which are independent of capsid control. For example, 1956 was one of those exceptionally good years (260,000 tons) for Ghana production in general, which could be the reason for the extremely high yield for this year in Figure 2. Figure 3 shows the same data used for Figure 2 with two corrections applied. Firstly, these histograms are an estimate of actual, rather than potential, crop. The estimates were arrived at by excluding all diseased, unripe pods harvested plus 56 per cent of the diseased ripe. The figure of 56 per cent is the best estimate available of the proportion of diseased, ripe pods containing beans destroyed by the fungus when trees are harvested every month. It is based on counts taken during 1958 on 16,000 diseased, ripe pods. Secondly, spraying did not start on six of the units until 1955. The data for these units has, therefore, been moved back one year and the yields expressed as averages for each year from the commencement of spraying. This

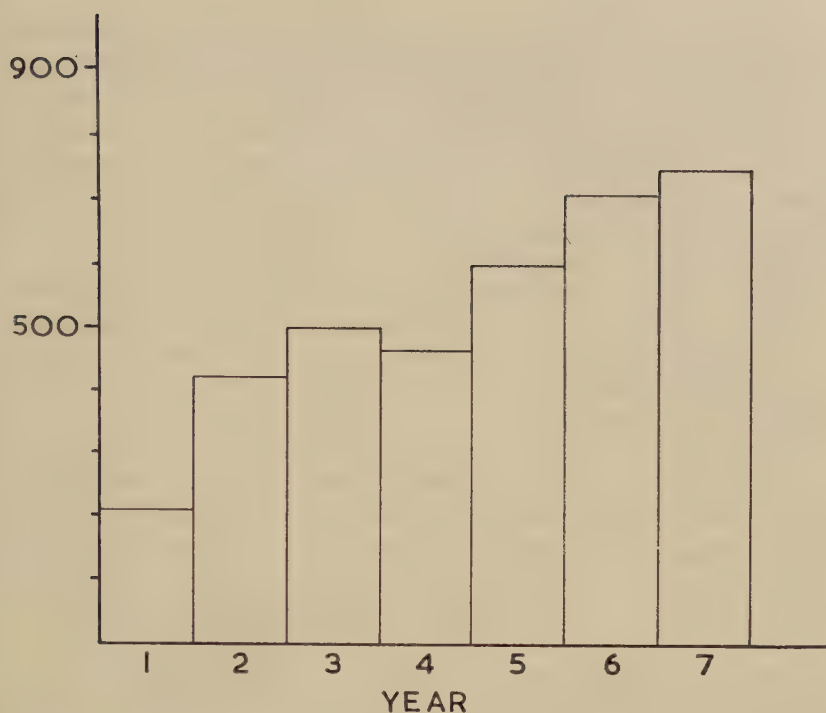


FIGURE 3. Estimated actual yield in lb. per acre of dry cocoa from capsid-sprayed plots in the Ministry of Agriculture 'capsid-yield-recorded units'. The estimate has been obtained by excluding all diseased, unripe and 56 per cent of diseased ripe, pods; the records for the six plots where treatment did not commence until 1955 have been moved back one year. (Assumed conversion rate, 12 pods equivalent to 1 lb. dry cocoa.)

does not give complete accuracy because it tends to obscure the seasonal variations in yield and levels of pod disease. However, Figure 3 still shows the general pattern of increase as in Figure 2, with good estimates of the actual yield in lb. dry cocoa per acre. It would appear that, while the crop was doubled after one year of spray-treatment, it subsequently increased in a more or less linear manner to three-and-a-half times the original crop 6 years later.

The increase in yields over 7 years may result from a continued general improvement in trees which had been severely blasted by capsid attack, in many instances the dieback extending to the main trunk. One additional suggestion is that the initial canopy regeneration was on those older parts of the trees which were still alive. However, the dieback was so severe on these trees that in many cases it was necessary to allow chupon regeneration from the base. These 'chupons' are now six years old and it is conceivable that in the fifth year they started to make an additional contribution to the yield of the older parts of the trees. It is important to realize that the

Ministry of Agriculture applied insecticide treatments and harvested the crop regularly at monthly intervals; there has been no deliberate effort to improve the cocoa units in other ways. Not all the cocoa in Ghana was so severely damaged by capsids as these experimental units but the latter were typical of very large acreages that had been severely damaged. Whatever the reason for these yield increases, it does appear that estimates that the cocoa crop might be doubled, by capsid control measures alone, were conservative.

Following the increases in yield during 1959 and 1960 it may now be possible to re-examine the question of whether the proportion of crop attacked by black-pod disease increases as the numbers of total pods increase (Blencowe & Wharton, *Proc. Sixth Commonw. mycol. Conf.* 1960, pp. 139-147).

The staff of the Cocoa Division of the Ministry of Agriculture is to be congratulated on the continued high standard to which these experiments are maintained; the results now include data from 7,600,000 classified pods and continue to yield information of great interest.

MEALYBUG STUDIES

JOINT W.A.C.R.I./DIVISION OF AGRICULTURE ANT-MEALYBUG CONTROL TRIALS

Methods of application and formulation (K. B. Armstrong)

Population assessments of ants and mealybugs have been recorded fortnightly since the commencement of the experiment in July 1959. The general details of experimental methods and treatments were published in *Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 37. This experiment will be terminated in December 1961 and the complete records will be published later. The purpose of the experiment was to determine which of the treatments would give ant control comparable to that achieved by treatment A, which was used in the Oyoko experiment (*Rep. W. Afr. Cocoa Res. Inst.*, 1957-58, p. 31), without causing an increase in minor pest damage as experienced at Oyoko (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 36).

Information at present supports earlier observation that a similar and acceptable reduction of ant and mealybug numbers was effected by treatments A, B and C. Treatment D, 10 per cent dieldrin urea-formaldehyde lacquer banding, was least effective as a control measure. Of the minor pests recorded, *Eulophonotus myrmeleon* Feld. was absent on untreated plots, but apart from Treatment D, its numbers were relatively high on all other plots. The incidence of the pod husk miner, *Marmara* spp., as recorded by the percentage of pod surface attacked, has been high on all plots.

On consideration of the assessments of minor pest damage made to date, it is apparent that the dieldrin treatments, however localized in application, upset the minor pest ecology of mature cocoa. Thus dieldrin, at the rates used in this experiment, is unlikely to prove satisfactory for field application in large areas of contiguous cocoa in Ghana. It is not yet known whether the main reason for the increase in the minor pest populations results from the dieldrin applications reducing the number of the pests' parasites or the numbers of predaceous ants.

Further work on the use of formicides for mealybug control is being carried out on plots of over 10 acres at Nankese and Koransang. The object again is to achieve ant control without raising minor pest damage to major proportions. Insecticide application at both plots is comparable to that of treatment (A) of the 'Method of Application and Formulation Trial', but differs in that 1 lb. actual chlordane and 1 lb. actual heptachlor are applied by mistblower in 20 gallons of water per acre, to the Nankese and Koransang plots respectively. The spray is directed to the trunks of both cocoa and forest trees and complete coverage is ensured to a height of 8 to 10 feet. The first application was made in February and the second spray was applied four weeks later in March. Assessment of ant mealybug and minor pest (*Eulophonotus*, *Tragocephala*, metarbelid 'webber', *Marmara*), populations are being made at fortnightly intervals.

ANT-MEALYBUG POPULATION STUDIES (E. Dunn)

Ecological studies were started in April 1960 to assess the importance of the different techniques of plantation establishments of cocoa at W.A.C.R.I. and the use of insecticides on the various species of mealybugs (Pseudococcidae) and attendant ants.

A survey is being made on two- and three-year-old Amazon cocoa plants growing at a 10 ft. spacing on four experimental plots, under different types of nurse shade, (A) tree cassava only; (B) plantains and tree cassava; (C) *Terminalia ivorensis*. Before planting, the secondary forest trees were felled in parallel rows and left *in situ* on two of the plots. From the other two the timber was removed after felling. With one exception, all plantings are being sprayed once a month with endrin 20 per cent emulsifiable concentrate, using 4 oz. actual toxicant in 5 gallons of water per acre. This spray controls the important lepidopterous pest *Earias biplaga* Wlk. and the mirids *Distantiella theobroma* (Dist.) and *Sahlbergella singularis* Hagl.

Three hundred and sixty random trees are examined every month, and the four most important mealybug vectors of cocoa swollen shoot virus recorded, namely: *Planoccoides* (*Pseudococcus*) *njalensis*

(Laing), *Ferrisiana virgata* (Ckll.), *Planococcus citri* (Risso), and *Pseudococcus bukobensis* Laing. *P. njalensis* is usually attended by either crematogasterine, camponotine or pheidoline ants, whereas *F. virgata*, *P. citri* and *P. bukobensis* are normally unattended.

The results to date appear to show differences between sprayed and unsprayed plots. *P. njalensis* is most numerous on the unsprayed plot and much reduced in numbers where monthly spraying with endrin has been applied. In contrast, *F. virgata*, *P. citri* and *P. bukobensis* are more numerous on the sprayed plots. If this population change following the application of endrin is real, it is very disturbing, since *F. virgata* is known to be as efficient a vector of the swollen shoot virus as *P. njalensis*. Both *P. citri* and *P. bukobensis* are also vectors. Since these three species of mealybugs are much more mobile than *P. njalensis*, any rise in their numbers could increase the risk of virus spread.

The low numbers of *P. njalensis* on the sprayed plots is associated with low attendant ant populations, the ants appearing to find difficulty in re-establishing large colonies because of the monthly spraying. On plots with heavy inter-row vegetation, however, ants seem to be increasing again.

With the two species of ants commonly found attending mealybugs, observations indicate that on the plots from which timber has been removed, *Crematogaster striatula* populations have declined but those of *Camponotus* sp. have increased. Such a change could be explained in terms of the different habitat requirements of the two species; crematogasterine ants live in dead branches whereas *Camponotus* species nest in the ground, and, if competition exists between the two, a reduction in the numbers of *Crematogaster striatula*, following the removal of nesting sites, could allow *Camponotus* sp. to increase in numbers.

CAPSID STUDIES

JOINT W.A.C.R.I./DIVISION OF AGRICULTURE CAPSID CONTROL TRIALS
(K. B. Armstrong)

This report summarizes the results of these joint capsid control trials carried out in the last four years. Application of insecticides as emulsifiable concentrates, in 5 gallons of water per acre, was made by motorized knapsack mistblowers, except where otherwise stated. Assessment of the relative capsid populations was made by recording fortnightly the trees showing fresh capsid feeding lesions and by a bi-annual assessment of cocoa canopy regeneration. The term capsid as used here refers to *Distantiella theobroma* (Dist.) and to *Sahlbergella*

singularis Hagl. no distinction between the two being made in the field.

Large scale trials

These trials were carried out in farmers' cocoa on three plots of approximately 100 acres. The plots were situated at Kwabeng, Awenare and Sankobenase. One application per plot of 4 oz. actual endrin, aldrin and dieldrin in June and July 1957 gave excellent control of capsids for three months with endrin being superior. A *gamma*-BHC treatment was substituted for that of dieldrin and applications of 1 oz. actual endrin, aldrin and *gamma*-BHC in November and December 1957 gave good control of capsids; endrin again giving the best results. In June and July 1958 the plots were retreated at the 1 oz. rate. At the end of 3 months, the fortnightly assessment of damaged trees was not more than 1 tree per acre for all treated plots and no further insecticide applications were made. Nine months after treatment, damage in the endrin plot was still at a low level whilst that in the aldrin plot and the *gamma*-BHC plot, although acceptable up to the sixth month, was unsatisfactory.

In 1959 the aldrin and *gamma*-BHC plots were sub-divided, one sub-plot of each receiving a single application of either $\frac{1}{2}$ oz. actual endrin, 4 oz. actual aldrin or 4 oz. actual *gamma*-BHC per acre. The treatments differed from all previous trials where two applications were made with a 4 weeks interval. After 3 months it was apparent that the single applications of aldrin and *gamma*-BHC at the 4 oz. rate were not achieving satisfactory control especially in the sub-units where pre-treatment damage assessment had been high. The experiment was therefore revised and the two plots re-allocated as full units to the following treatment: on the one plot (Awenare) where damage assessment was lowest, (843 damaged trees in 117 acres), application of $\frac{1}{2}$ oz. actual endrin per acre was made twice yearly in November and June. On the other plot (Sankobenase) where damage was higher, (2,043 damaged trees in 95 acres), the same rate of endrin was applied three times per year in November, March and July. On both plots, from the first application until the present, (March 1961), fortnightly assessment of all trees in the plots showed less than one tree per acre with fresh capsid feeding lesions; furthermore the greater proportion of damage has been recorded on the margins of the plots. Virtually 100 per cent control of cocoa capsids has therefore been achieved on these plots for periods of six and four months with the very low dose of $\frac{1}{2}$ oz. actual endrin per acre. The effectiveness of the control measures was shown to be correlated with the large size of the plots.

Small scale trials

The application of the results of the large scale capsid trials is not strictly permissible in Ghana at present since individual farms are seldom bigger than 7 acres in size. In order to conform to actual farming conditions replicated plots of 2 acres were laid out in farmers' cocoa in the Kwahu Tafo area. Following the success of $\frac{1}{2}$ oz. double applications of endrin twice yearly (June and July; November and December), on 3-4 acre plots (Johnson and Dunn, *Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 40), five plots were allocated at the Kwahu site to each of the following treatments:

- A. $\frac{1}{2}$ oz. actual endrin per acre applied three times a year, in November, March and July.
- B. 1 oz. actual endrin per acre applied three times a year, in November, March and July.
- C. A standard *gamma*-BHC treatment of a 4 oz. per acre initial application in June and July with 1 oz. applications thereafter in November and December, June and July.

In March, when the second endrin application became due, capsid control under treatment A was not considered acceptable and the treatment was discontinued. The poor control is in marked contrast to the excellent results achieved by $\frac{1}{2}$ oz. endrin sprays to 100 acre plots in the large scale trial. This is undoubtedly due to the rapid re-infestation at the periphery of small plots. The five plots allocated to treatment A were then sprayed with sevin at $1\frac{1}{2}$ lb. actual toxicant per acre formulated as a 50 per cent wettable powder (Treatment A1). This insecticide had shown considerable promise in laboratory screening tests (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 42). Single applications only were used, since no retreatment after four weeks could be made if dosages were to bear an economic comparison with other capsicides. Control of capsids proved to be unsatisfactory and was very similar to that achieved by the application of $\frac{1}{2}$ oz. endrin. Retreatment of the endrin (B) plots in July and the *gamma*-BHC (C) plots in June and July respectively was made at 1 oz. a.i. per acre. One-and-a-half pounds actual sevin, formulated as the 85 per cent sprayable concentrate (Treatment A2), was applied to the plots previously treated with the 50 per cent wettable powder. Treatments B and C continued to give excellent capsid control. Results with sevin were again poor although it is possible that a double application would result in a satisfactory control of capsids. This would, however, only be practicable if cost of the insecticide become more economic. Assessments of the regeneration of canopy made in November 1959, June and December 1960 showed improve-

ments in plots receiving treatment B and C but not in those plots which had received successive treatments A, A₁ and A₂.

There is no indication that the cocoa capsid in Ghana is developing resistance or tolerance to the chlorinated hydrocarbon insecticides which are most commonly used and control is still being maintained at W.A.C.R.I. and on Division of Agriculture stations after 5 years of regular treatment at the recommended dosage rates. However, alternative insecticides have been screened in the laboratory (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 40) and the more promising are being tested in the field.

Pyrethrins were tested in the field when a supply of 6 per cent pyrethrins water miscible concentrate was made available. Since this spray has no persistence it was hoped that control of capsids would be achieved by a very rapid and complete knockdown. Laboratory screening had, however, indicated that capsids were not particularly susceptible to pyrethrin sprays. Sixteen two-acre plots, balanced for tree density and pre-treatment capsid damage, were allocated four to each of the following four treatments:

- A. 0.4 per cent pyrethrins applied by mistblower at the rate of 5 gallons of solution per acre.
- B. 0.16 per cent pyrethrins applied by mistblower at the rate of 5 gallons of solution per acre.
- C. 0.16 per cent pyrethrins applied by mistblower at the rate of 10 gallons of solution per acre.
- D. Untreated control.

The number of trees showing fresh capsid damage following application of the treatments twice at a month's interval was lowest on the untreated control plot. There was little difference in damage assessment between the treated and untreated plots and it is evident that application of pyrethrins at the rates used above does not control capsids.

In January 1961 a comparison of the efficacy of two organophosphorus insecticides was made with that of the standard *gamma*-BHC treatment. The ten plots previously used for sevin (A) and endrin (B) treatments at Kwahu Tafo were reallocated and matched as two groups of five plots on the basis of the recent capsid damage figures. One-and-a-half pounds per acre actual Dipterex as an 80 per cent soluble powder was applied to one group and slightly more than 1½ oz. (45 cc.) per acre actual Lebaycid (Bayer S.1752) as a 50 per cent emulsifiable concentrate, to the other. Preliminary results with Lebaycid are encouraging and field trials are being extended. Dipterex gave only poor control of capsids and treatment has been stopped.

These trials on both large and small scale plots are being continued with the object of finding cheaper and more efficient capsicides than those used at present, as well as more economic rates and improved methods of application.

POLLINATION STUDIES

(B. M. Gerard)

McKelvie has shown (*Rep. W. Afr. Cocoa Res. Inst.*, 1956-57, pp. 59-64) that pollination by natural agents at Tafo is efficient enough to allow more cherelles to develop than the individual trees will carry to maturity. Thus, since the population of pollinating agents at Tafo is more than adequate to obtain the present yield of cocoa pods it is of interest to find the specific identity of these agents, to estimate the size of the populations and to determine the environmental conditions necessary for maintaining these populations.

The results of previous research on pollination of cocoa show that midges of the genus *Forcipomyia* (Ceratopogonidae; Diptera) are mainly responsible for successful pollination, especially with self-incompatible varieties of *Theobroma cacao* L.

Research during 1960-61 has been confined to sampling for *Forcipomyia* larvae in habitats found by Mrs Entwistle to contain larvae, and to culturing on natural media, so that adults and their larvae can be recognized.

A study of the effects of insecticides upon the adult midges, and upon the larvae is also being made. Preliminary information on flower production, setting, cherrille wilt and pod yield is being taken by means of daily records on an 8-acre plot which receives the standard BHC treatment against capsids. When sufficient records have been obtained it is planned to study the effects of different insecticides and dosage rates in this plot.

MINOR PESTS

NURSE SHADE V. NO SHADE EXPERIMENT (M. R. Smith)

The layout of this experiment has been described (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 43). The removal of nurse shade (mostly tree cassava) in the appropriate plots was completed in early March 1960. Spray treatments were not applied until September 1960. The experimental trees are comprised of the following varieties in the proportions given in parenthesis: F₂ T12 (2), WEB2 (3), WAE 11 (6), WE4 (1), WEB 1 (5), WAE 5 (4) and F₁ T82 (15).

Within two months of the completion of shade removal many of the cocoa trees in the de-shaded plots were in an unhealthy condition.

The majority of these de-shaded trees lost many of their terminal buds and some shed their leaves, especially from the distal parts of the branches. Leaf fall was followed in many cases by a form of die-back which started at the budless apex of the fan branch and stopped at the jorquette. The nature of this die-back was not ascertained. Much of the initial bud damage was caused by lepidopterous larvae, principally *Earias biplaga* Wlk., but some may have been caused by other factors such as sun scorch and the Cocoa Psyllid. Leaf fall was probably brought about by physiological drought. New leaves produced by the trees were frequently eaten or damaged by lepidopterous larvae.

Some varieties of cocoa, notably F₁ T82 and WEB 2, were able to withstand the conditions caused by de-shading better than others and grew branches and leaves in excess of those lost or damaged. Trees of these varieties developed a thick bushy form because of the production of numerous lateral branches. The least vigorous variety under these conditions was WAE 11. Trees of this variety were unable to replace the damaged tissue at a sufficient rate and by the end of August 1960 many of them were dead above the jorquette and entirely leafless.

During this time the trees in the shaded plots were healthy and not suffering from leaf-fall or die-back. The largest of the shaded trees had less foliage than the most vigorous de-shaded trees but the shaded trees had a more open branching system and were considered to be a better shape.

Figure 4 compares the average number of mature leaves on shaded and de-shaded trees as determined by approximately fortnightly counts carried out on three trees, chosen at random, in every plot (i.e. each sample consisted of 6.25 per cent of the total experimental trees and it contained all varieties of cocoa in the proportions mentioned earlier). It can be seen that up to the middle of March 1960, the average number of leaves on shaded and partly de-shaded trees was similar but subsequently the average number of leaves per de-shaded tree dropped and remained low during April and May whereas there was no drop in the average number of leaves per shaded tree over the same period. By the end of 1960 the average number of leaves per shaded and de-shaded tree were again very similar. As several varieties were involved the cocoa lacked uniformity, consequently there were considerable deviations from these averages especially in the de-shaded plots.

Many species of Lepidoptera have been recorded from within the experimental area, and one of the most important is *E. biplaga*, the larvae of which damages buds and young leaves. The first instar larva of this species usually bores into a bud and eats the young

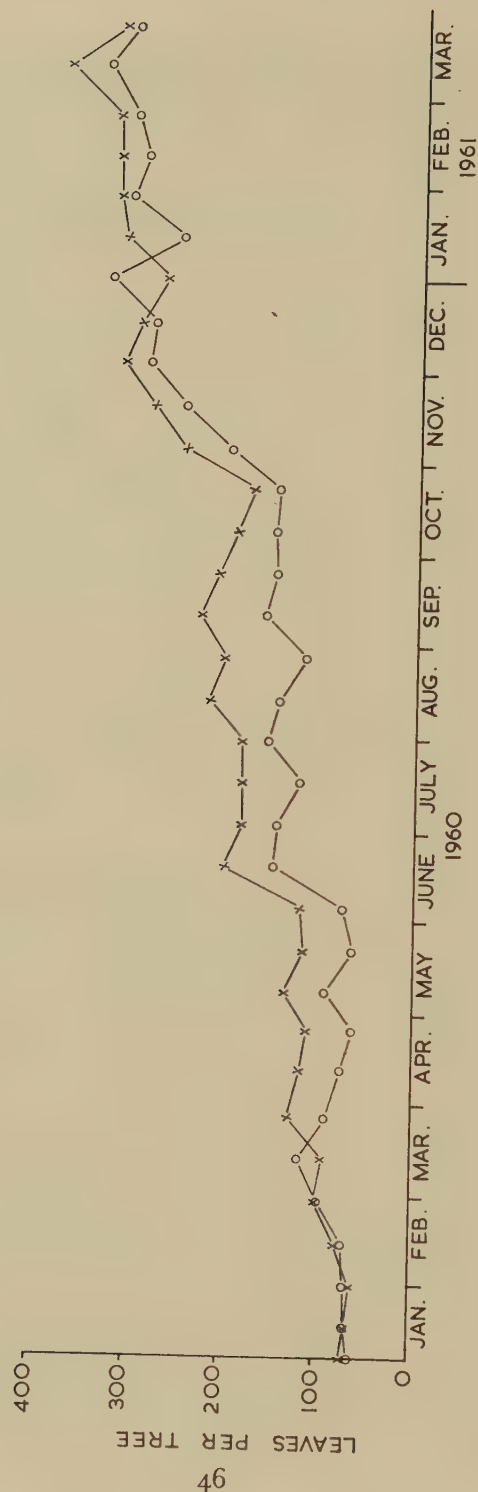


FIGURE 4. Comparison of the average numbers of mature leaves on shaded (x-x-x) and on de-shaded (o-o-o) trees.

inner tissue, leaving the outer parts more or less intact. When the inside of the bud has been consumed the larva moves to another bud or to a young leaf. Bud damage caused by first instar larvae is difficult to detect until the buds die, by which time the larvae have moved elsewhere.

Bud damage caused by mature larvae is more easily recognized because greater damage is caused to the outer parts and bigger larvae cannot conceal themselves within the buds.

Figure 5 shows the average number of *E. biplaga* larvae, excluding those concealed inside buds, on shaded and de-shaded trees as determined by approximately weekly counts on 5-7 trees per plot. After September, when certain plots were sprayed for the first time, the figure shows the averages for unsprayed plots only. It can be seen that *E. biplaga* larvae have generally been much more abundant on de-shaded trees. During the first few months of 1960 the difference was less noticeable; however, shade removal was not completed until March and the shade in the shaded plots was less dense than later in the year.

Larger numbers of *E. biplaga* larvae were recorded in the early part of 1960 than during the rest of the year and in 1961 there was a well defined peak in January followed by a depression in February and a second, smaller peak, towards the end of March. The reasons for these high numbers in the early part of the year is not clear. At times during the dry season there may be little new growth on the cocoa trees and larger numbers of *E. biplaga* larvae just before, or at, the beginning of the dry periods are particularly dangerous, because the following generation of larvae is liable to damage a greater proportion of the young tissue available, especially buds if young leaves are scarce.

In September one-third (12) of the plots were sprayed with Dipterex '80 S.P.' at the rate of 24 oz. in 12 gallons of water per acre. Another third of the plots were sprayed with Sevin '85 sprayable' at the rate of 14 oz. in 12 gallons of water per acre. The remaining twelve plots were left unsprayed. Spray treatments were repeated approximately fortnightly. A total of 538 *E. biplaga* larvae, counted in randomized samples between 20th September 1960 and 30th March

TABLE 16
Numbers of E. biplaga larvae

	<i>Shade</i>	<i>No Shade</i>
Sevin	19	52
Dipterex	18	81
Control	44	324
<i>Totals</i>	81	457

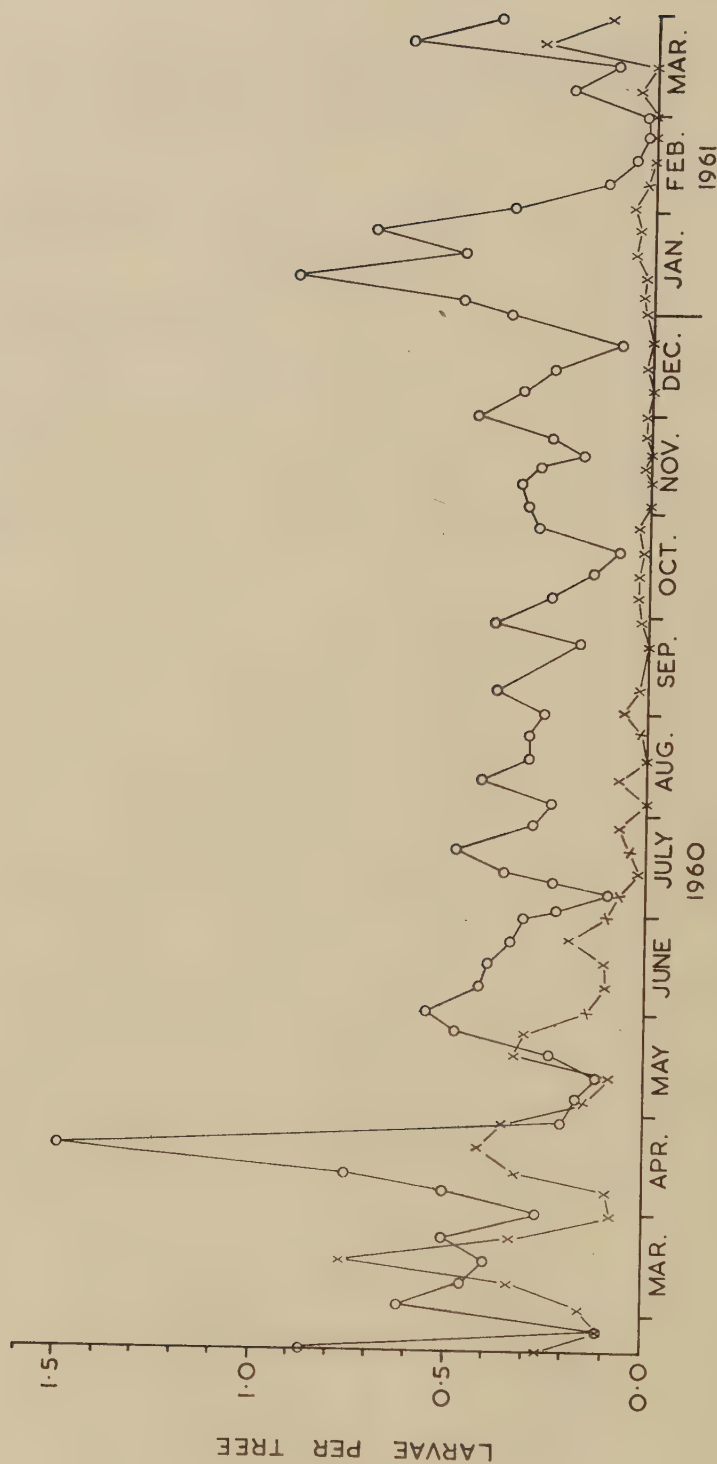


FIGURE 5. Comparison of the average numbers of *Earias biplaga* larvae (excluding those inside buds) on shaded (x-x-x) and on de-shaded (o-o-o) trees.

1961, were distributed in the experimental area as shown in Table 16.

Both insecticides controlled *E. biplaga* to some extent but it is noticeable that fewer larvae were observed in the unsprayed shaded plots than in the sprayed unshaded plots.

LEPIDOPTERA (M. R. Smith)

A collection of Lepidoptera and parasites of Lepidoptera associated with cocoa has recently been sent to the Commonwealth Institute of Entomology for identification and it is hoped that a list of these will appear in the next Annual Report.

A list of Lepidoptera associated with cocoa has been published (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, pp. 43-45). The larvae of most of these Lepidoptera eat the young leaves. A list of the common exceptions to this rule is given below. The list includes some species not mentioned previously.

LIMACODIDAE

Semyrilla lineata Holl.

Parasa viridissima Holl.

Omocena convergens Hering

Latoia vitelina Karsch

Latoia viridifascia Holl.

Casphalia flavicollis Wlk.

Baris elsa Druce

The final instar larvae and at least some of the younger larval instars of all species eat only mature leaves.

COSSIDAE

Eulophonotus myrmeleon Feld. The larvae bore in the wood of the main trunk and branches.

GRACILLARIDAE

Marmara sp. Larvae mine beneath the epidermis of pods and young shoots (both fan-branches and chupons).

NOCTUIDAE

Anomis leona Schaus. Larvae mostly eat young leaves but occasionally older leaves and cherelles.

Characoma stictigrapta Hmps. Larvae frequently bore into the pericarp of pods and occasionally damage the beans. Also commonly found on young leaves and chupons.

Earias biplaga Wlk. Larvae eat buds as well as young leaves.

PYRALIDAE

Sylepta retractalis Hmps. Larvae eat mature leaves.

TABLE 17
Yields from the Amelonado spacing experiment

Spacing	15' × 15'	12' × 12'	10' × 10'	7½' × 7½'	7½' × 6'	6' × 6'	5' × 5'	4' × 4'
Equivalent density (trees per acre)	193	302	435	774	968	1,210	1,742	2,722
Pods per tree								
1959-60	49.4	59.5	54.3	31.6	22.6	18.6	13.1	8.8
1960-61	101.0	102.8	76.6	44.6	34.4	29.0	19.9	12.9
Dry cocoa per acre (lb.)								
1959-60	795	1,487	1,969	2,007	1,828	1,877	1,912	1,997
1960-61	1,623	2,588	2,765	2,878	2,765	2,897	2,894	2,929*

* 1960-61 Yields, L.S.D. 229 lb. at 1 per cent level.

TABLE 18
*Amelonado spacing experiment—distribution of crop.
Percentage of total pods in canopy and on trunk*

Spacing	15' × 15'	12' × 12'	10' × 10'	7½' × 7½'	7½' × 6'	6' × 6'	5' × 5'	4' × 4'	Mean
Trunk									
1959-60	57.7	53.9	54.1	72.4	71.5	73.1	82.9	87.9	62.4
1960-61	39.2	35.6	38.7	48.7	61.0	63.4	70.2	74.7	44.5
Canopy									
1959-60	42.3	46.1	45.9	27.6	28.5	26.9	17.1	12.1	37.6
1960-61	60.8	64.4	61.3	51.3	39.0	36.6	29.8	25.3	55.5

SATURNIDAE

Nudaurelia dione F.

Imbrasia epimethea Dry.

Final instar larvae and at least some of the younger larval instars of both species eat mature leaves.

MARMARA STUDIES (B. M. Gerard)

Basic information about the life history of *Marmara* sp. (Gracilariidae; Lepidoptera) is being obtained. Surveys of the populations in W.A.C.R.I. Square Mile area have been started to give an indication of distribution and seasonal fluctuations.

The objects of these studies will be to discover the reasons for the sudden increase in numbers of *Marmara* larvae on cocoa pods which is often associated with applications of dieldrin; and especially to suggest conditions suitable for keeping the populations under control.

ESTABLISHMENT AND MAINTENANCE EXPERIMENTS

(T. H. R. Hall)

SPACING EXPERIMENTS

Amelonado cocoa

The yields for the thirteenth year of the Amelonado Spacing Trial are shown in Table 17.

The yields at all spacings were substantially greater than those of the previous year, the overall increase being about 50 per cent. This year the yield of the $7\frac{1}{2}$ ft. $\times$ $7\frac{1}{2}$ ft. spacing, which has consistently given the best crop over the past years, was not significantly different from that of the other close spacings.

The distribution of crop between canopy and trunk shown in Table 18, displays a different pattern from last year, and the overall distribution has been reversed to show a higher proportion of the crop borne in the canopy. The yield of pods in the canopy increased by 138 per cent while those on the trunk increased by only 17 per cent.

From the earlier results of this trial Smith (*J. hort. Sci.*, **35**, 176-184, 1960) has concluded that the fall in yield of cocoa at high density plantings is due to intense competition for nutrients and lack of adequate root space per individual tree. This year's substantial increase in the yield of cocoa at densities greater than 1,700 stands per acre suggests that when environmental conditions are favourable highest yields are obtained from cocoa planted at 10 ft. $\times$ 10 ft. or closer, after the removal of forest tree shade and the addition of fertilizers.

Amazon cocoa

Table 19 shows that the overall yield from the Upper Amazon spacing and pruning experiment increased by 48 per cent compared with the previous year.

TABLE 19
Yields from the Upper Amazon spacing and pruning experiment

Spacing	8' × 8'		10' × 10'		12' × 12'	
Equivalent density ...	680		435		302	
(trees per acre)	1959-60	1960-61	1959-60	1960-61	1959-60	1960-61
<i>Unpruned</i>						
Pods per tree ...	25.8	32.1	43.5	53.4	55.1	91.7
Dry cocoa per acre (lb.) ...	1,423	1,818	1,581	1,936	1,388	2,308
Percentage of crop in canopy ...	74.3	60.0	74.1	66.1	81.0	71.6
<i>Pruned</i>						
Pods per tree ...	20.1	27.4	30.3	53.0	40.7	68.6
Dry cocoa per acre (lb.) ...	941	1,555	1,113	1,920	1,168	1,721
Percentage of crop in canopy ...	77.3	57.1	77.1	71.4	83.2	70.9

Whereas last year the highest yield was realized at the 10 ft. × 10 ft. spacing, this year it was given by the 12 ft. × 12 ft. spacing.

The distribution of the crop shows a greater difference with spacing than previously. The tendency for the percentage of the crop in the canopy to increase with increase in spacing is apparent for both years.

PRUNING EXPERIMENTS

Amelonado cocoa

In the second establishment experiment the pruned plots gave a lower yield than the unpruned plots, 1,807 lb. compared with 2,954 lb. dry cocoa per acre, the difference being significant at the 5 per cent level of probability.

In the small pruning experiment in Block P, the pruned plots gave a yield of 672 lb. dry cocoa per acre, and the unpruned plots 649 lb. per acre. The difference in yield however is not significant.

Amazon cocoa

The unpruned cocoa in the Amazon spacing experiment gave a significantly ($P=0.05$) higher yield of 13.7 per cent more pods than the pruned cocoa. Since bearing commenced nine years ago, the average annual yield of dry cocoa per acre in the unpruned cocoa has been 639 lb. and that in the pruned cocoa 593 lb., the difference being significant ($P=0.05$).

The second year's crop in the Amazon tree-forming experiment was small, but the pruned cocoa gave a significantly higher yield than the unpruned cocoa.

SHADE EFFICIENCY EXPERIMENT

At the beginning of the rains, the shade crop was drastically thinned and afterwards when required until the end of October. The trash from the banana and plantain plots was laid along the cocoa rows as a mulch thereby reducing weed growth. The reduction of weeds was more marked in the banana plots, because the volume of trash was greater than in the plantain plots. Stem diameter at 5 cm. from the ground and the height to first jorquette were measured, while samples of weed growth in each plot were also taken. During the dry season the moisture content of the soil under the different shade regimes was measured at weekly intervals. The results are summarized in Tables 20 and 21.

TABLE 20
Shade efficiency experiment 1960-61

<i>Type of nurse shade</i>	<i>Plantain</i>	<i>Banana</i>	<i>Tree Cassava</i>	<i>Tree Cassava and Plantain</i>	<i>L.S.D. at 5% level</i>
Diameter of trees 5 cm. above ground on 3/11/59 (cm.) ...	0.93	1.02	0.97	0.94	0.07
Diameter of trees 5 cm. above ground on 24/4/61 (cm.) ...	4.2	4.0	4.6	4.3	0.35
Increase in diameter (cm.) ...	3.3	2.9	3.6	3.3	0.49
Fresh weight of weed growth cut per plot on 11/4/60 (lb.) ...	24	16	30	28	11.1
Fresh weight of weed growth cut per plot on 6/9/60 (lb.) ...	16	12	22	20	4.8
Fresh weight of weed growth cut per plot on 30/3/61 (lb.) ...	5	6	9	6	2.8
Total fresh weight of weed growth ...	46	34	61	54	15.1
Number of man hours required to cut weed growth ...	8	5½	14	11½	—
Height of first jorquette (m.) ...	1.15	1.12	1.11	1.07	N.S.

TABLE 21
Shade efficiency experiment: soil moisture content (per cent)

<i>Type of Shade</i>	<i>Plantain</i>	<i>Banana</i>	<i>Tree Cassava</i>	<i>Tree Cassava and Plantain</i>
December 1960	19.2	21.8	18.3	20.0
January 1961	13.4	17.6	13.6	12.9
February 1961	13.5	16.1	12.8	11.1
March 1961	16.9	15.6	13.6	13.5
April 1961	19.3	23.0	18.1	17.2
Mean	16.5	18.8	15.3	14.9

L.S.D. at 0.1 per cent = 2.16

L.S.D. at 1 per cent = 1.60

The increase in stem diameter of the cocoa grown under banana was significantly less than that under the other shade regimes.

The generally higher moisture content under bananas can be attributed to the heavy mulch. The first pods were harvested from these plots at the end of February, only eighteen months after the experiment was planted.

NEW EXPERIMENTS

Thinning experiment

The purpose of this experiment is to find out if the higher yields and reduced maintenance costs obtained from closely planted cocoa in the early years of bearing offset the increased costs of establishment.

Cocoa has been planted at 5 ft. $\times$ 5 ft. and when necessary will be thinned to 10 ft. $\times$ 10 ft. Four different thinning treatments replicated ten times in a randomized block design will be tried. The four treatments are:

- A. Planted at 5 ft. $\times$ 5 ft. and to be thinned to 10 ft. $\times$ 10 ft. by judgment of the canopy.
- B. Planted at 5 ft. $\times$ 5 ft. and thinned to 10 ft. $\times$ 10 ft. by removal of alternate trees in 2 stages.
- C. Planted at 5 ft. $\times$ 5 ft. Trees at 10 ft. $\times$ 10 ft. spacing to be allowed to develop, and alternate trees to be restricted in growth to the first jorquette.
- D. Control—planted at 10 ft. $\times$ 10 ft.

The experiment was planted in mid-July, and because of unfavourable weather subsequent to planting and the severe dry season the seedlings have not established well and 15 per cent have died.

Management studies on clonal cocoa

One-and-a-half acres were planted in June with rooted cuttings of Na 32 and Pa 35. Half of the area was planted with the fan branches orientated in one direction while in the other half, no attention was paid to direction of the fan branches. The purpose of this trial is to study methods of growing and tending clonal cocoa.

Hybrid shade and manurial experiment

Part of the Hybrid shade and manurial experiment which will occupy 10 acres was planted early in July. Each main plot of $2\frac{1}{2}$ acres consists of one Hybrid, and is split for fertilizer and shade treatments. The four Hybrids used in this planting are F₁ T82, WBE₄, WBE₃ and WAE₁₁. Again the dry weather affected the establishment and 15 per cent of the seedlings were lost within the first month. These

losses were replaced in September. Subsequent losses during the dry season were only 5 per cent despite the poor establishment of tree cassava and the virtual failure of other shade trees.

SEED GARDEN

One acre of seed garden comprising two discrete units of half-acre each were planted with clonal material of T85/799 in one unit and T63/971 in the other. Each unit is surrounded by local Amelonado plantings to act as pollinators. Advantage was taken of the early rains in April to plant, and establishment was very good. A fertilizer dressing was applied in October, while weeding and the thinning of the plantain shade was carried out at regular intervals.

VEGETATIVE PROPAGATION

Cutting production potential of cocoa clones

The clones in the clonal nursery which were coppiced in February 1960 (*Rep. W. Afr. Cocoa Res. Inst.*, 1958-9, p. 60), regenerated sufficiently by August to permit the selection of suitable rooting material. The first harvest of rooting material was made in August 1960, and thereafter at weekly and monthly intervals. Results to the end of March 1961 are given in Table 22.

Before removing cuttings, a count was made of the number of shoots produced by each stool, in the hope that it would be possible to obtain a guide as to the future cutting production of each clone. It will be observed from Table 22 that the order of superiority for cuttings taken and number of shoots produced differs considerably. It is considered that had the cuttings been taken as and when they were in a suitable condition for rooting and not at a pre-determined interval, this difference in order of superiority might not have been so great, because the phasing of the flush-hardening cycle has been observed to vary from clone to clone and also from individual plants within the same clone. When comparing the performance at the first harvest of cuttings and the total amount obtained up to the end of March, clones which displayed a marked superiority or inferiority in the early stages of the experiment continued to do so, for example T79/416, T79/501. Exceptions to this however are found in the performance of E1 clone, which ranked third at the beginning but eight months later was ranked sixteenth. Whereas T12/26 was ranked third from the bottom on the first count, it gained ascendancy to eighth position. From the results it would appear that the initial performance of each clone is a good indicator of its future behaviour as far as production of cuttings is concerned. Whether or not the same superiority will be displayed in their rooting ability remains to be seen.

TABLE 22

Cutting production experiment: number of coppiced shoots and cuttings from 20 trees

<i>Clone</i>	<i>Number of shoots</i>	<i>Clone</i>	<i>Number of cuttings</i>
Tg/67	246	T79/416	4,084
Eg:B31/195	235	Tg/67	4,013
SC.1	212	T79/501	3,103
Tf.1	210	Tg/21	2,440
U.11	204	SC.1	2,346
X40/1452	202	Tf.1	2,327
E1 Clone	201	T60/887	2,311
B2	195	T12/26	2,196
Tg/21	191	U.11	2,190
N38	185	Eg:B31/195	2,131
E1:C43/270	181	R15	2,051
T79/416	176	Tf1/148	2,051
Tf1/148	173	B2	1,918
N38/91	169	X40/1452	1,871
Tf1/116	162	N38	1,624
E1:J92/70	152	Tf2	1,604
T60/887	151	E1 Clone	1,534
S27	150	S27	1,451
Tf2	150	N38/91	1,284
E1:C43/291	149	S36	1,143
T79/501	147	Tf1/116	1,119
T60/886	135	W41	1,111
A196	134	Tf2/331	1,103
W41	131	T60/886	1,076
S36	129	E1:C43/270	1,056
T12/26	128	E1:C43/291	1,013
Con. D4/4/4	120	E1:J92/70	869
P4/9J11:45	114	A196	851
Tf2/331	107	P4:9J11/45	844
R15	104	Con. D4/4/4	774
Std dev.	±11.4		±136

By taking cuttings at weekly intervals a total of 28,439 for all clones was obtained compared with 25,049 at monthly cutting intervals, the difference being significant at the 1 per cent level. In most cases more cuttings were obtained for each clone at weekly than at monthly intervals. The assessment of the rooting potential of clones has only started recently, following completion of structural alterations to the propagator, and no results are available.

PLANT BREEDING AND SELECTION

(D. R. Glendinning)

YIELDS AT W.A.C.R.I. 1960-61

Table 23 shows the yields from the main Botany plots in the 1960-61 season and, for comparison, those for the 1958-59 and 1959-60 seasons. Table 24 shows some individual yields.

TABLE 23
Pods harvested from the main Botany plots

	<i>Year planted</i>	<i>Experimental area (acres)</i>	1958-59	1959-60	1960-61
Trinidad Introductions	1945	12.3	122,500	141,000	168,000
1st Clonal trial	1947	4.4	58,000	65,000	51,000
2nd Clonal trial	1948	2.8	30,000	39,000	22,000
8th P.T.A.	1952	1.9	19,500	31,000	31,500
9th P.T.A.	1954	5.2	68,000	89,000	93,000

TABLE 24
Performance of some selections 1960-61

	<i>Spacing</i>	<i>Age from planting out (years)</i>	<i>Estimated yield dry cocoa (lb./acre*)</i>	
			<i>Potential†</i>	<i>Net</i>
<i>Trinidad Introductions</i>	14' × 14'	16		
T60			2,900	2,500
T6			2,600	2,200
T57			2,500	2,200
T65			2,100	2,000
T76			2,100	1,600
T79			2,100	1,700
T82			2,100	1,500
<i>Clones</i>				
1st Clonal trial	10' × 10'	14		
A36			1,800	1,000
ACu85			1,200	1,000
K5			1,550	900
U11			1,500	900
2nd Clonal trial	8' × 8'	12½		
TF1			1,500	950
R15			1,500	800
U6			1,300	1,050
B1			1,150	800
3rd Clonal trial	12' × 12'	5		
T79/501			714	521
T72/1767			664	471
T60/1774			615	400
<i>Crosses</i>				
8th Progeny trial	8' × 8'	9		
WAE4			2,850	1,950
WAE5			2,250	1,800
WAE3			2,100	1,450
WBE3			2,000	1,300
9th Progeny trial	10' × 10'	7		
WAE11			2,100	1,700
WEA3			1,800	1,450
WEB1			1,750	1,300
WE6			1,600	1,400

*Based on an assumed conversion rate of 40 per cent, on fermenting and drying the wet beans.

†The large differences between 'potential' and 'net' yields in some of the trials are due to pod-disease incidence having been permitted to build up to allow accurate assessment of varietal susceptibilities.

Table 25 gives the average yields of the Series II trials for the 1958-59, 1959-60 and 1960-61 seasons, and Table 26 gives the yields for the 1960-61 season in more detail. While conditions vary widely from site to site it will be seen that in general these varieties are doing well, and at some sites very well indeed.

TABLE 25
Series II Trials, average yields per year
(*lb. dry cocoa per acre**)

Planted 1956:—	1958-59	1959-60	1960-61
Apedwa	30	560	900
Asikuma	0	70	230
Pankese	70	360	780
Planted 1957:—	1959-60	1960-61	
Fumso	380	830	
Foso	0	230	
Buaku	NA	750	
Akaa	0	80	

*Yields estimated assuming a conversion of 40 per cent on fermenting and drying the wet beans.

NA=data not available.

TABLE 26
Yields in the Ghana Series II Trials, 1960-61 season
(*lb. dry cocoa per acre**)

														<i>Varieties</i>							
		A	B	C	D	E	F	G	H	J	K	L	M								
Trials planted in 1956																					
Apedwa ...		—	—	840	790	—	990	—	1200	890	890	720	850								
Asikuma ...		200	240	—	160	270	150	—	300	270	—	250	—								
Pankese ...		710	590	900	660	870	770	750	970	—	—	—	—								
Trials planted in 1957																					
Fumso ...		840	—	1090	370	770	970	630	800	—	1170	—	—								
Foso ...		210	360	330	90	210	210	210	250	—	—	—	—								
Buaku ...		—	870	680	600	760	830	500	870	—	910	—	—								
Akaa ...		30	110	120	—	60	90	—	120	—	60	—	—								

*Yields estimated assuming a conversion of 40 per cent on fermenting and drying the wet beans.

STUDIES ON INCIDENCE OF POD DISEASE AND RODENT DAMAGE

Trinidad Introductions

Data on losses due to pod disease on Amazon varieties over the period 1953-1955 have been studied. Losses were markedly heavier on Nanay varieties than on Parinari or Iquitos varieties or on hybrids Nanay × Parinari or Iquitos. There is a suggestion however that all the parent clones from which our Nanay varieties were

obtained may not carry the factor for high susceptibility (e.g. possibly Na33) and that some that do carry it may have it in the heterozygous condition (e.g. Na34). It seems probable that Parinari 7 carries a dominant character for low susceptibility in the homozygous condition.

An estimate of rodent damage for a small section of the area was prepared by subtracting the pod disease percentage from the overall percentage of discarded pods. Losses appeared substantially higher on Nanay $\times$ Parinari hybrids, especially Na32 $\times$ Pa7 and to a lesser extent Na32 $\times$ Pa35, than on pure Nanay types or Nanay $\times$ Iquitos hybrids.

Third Clonal Trial

Preliminary study of the 1960-61 data from this trial indicates:

Pod disease losses were nearly 50 per cent on R15, a known susceptible type from the 2nd Clonal Trial. No other clone had more than about 27 per cent losses.

There was a wide range in losses between different T60 and T79 clones, i.e. F₁ hybrids between Na32 and Pa7 (7 to 27 per cent, six clones). The significance of this variation has not yet been tested. ACu85 had light losses (8 per cent) as also T12/113 (9 per cent) though the latter variety suffered severely from rodents (see below). Other varieties were in the range 14 to 24 per cent.

T12/113 had nearly 70 per cent of its pods damaged by rodents, while no other variety had more than 22 per cent damaged. T85/799 was least attacked (3 per cent) while T63/882, T63/971 and T67/1224 lost only from 4 to 6 per cent. T85 is a hybrid progeny between Nanay 34 and Iquitos 60, while T63 and T76 both have Parinari 35 as one of their parents, crossed to Nanay 32 and Nanay 31 respectively. ACu85, R15, T16/613 and T72/1767 lost from 9 to 14 per cent, while the six Nanay 32 $\times$ Parinari 7 clones (T60 and T79) lost from 10 to 22 per cent.

Series I Trials

The parent trees of a given variety are not identical in all trials, e.g. 'T60' in the Bunso trial is T60 stand 1773 $\times$ stand 972, in the Bechem trial stand 888 $\times$ stand 885, and in the Juaso trial stand 1049 $\times$ stand 1774. Usually this is of little importance, but as there is evidence of genetic segregation for pod disease susceptibility in some of the Amazon populations it is of significance in this case. It would be misleading to treat these various crosses within a 'T type' as being a single variety, so it is not easy to present a generalized picture. However Amelonado is among the least heavily infected varieties in all the trials yet studied in detail. With the possible exception of

T85, it also tends to be the least attacked by rodents. The narrower cropping season of Amelonado may be of significance in reducing rodent attack, but data from the Bunso Series I Trial over a period when all varieties were yielding very heavily clearly indicate selective attack by rodents on T60 (Table 27).

TABLE 27
Bunso Series I Trial; Rodent attack on pods
(Harvests from 27 September to 12 November 1960)

	Numbers of pods attacked	
	T60 100 trees	Three other varieties 300 trees
Block IV (Roadside)	11	0
III	18	5
II	55	5
I (Inner)	96	18
Total pods harvested:—	3,142	5,954

Series II Trials

The Series II varieties unlike those of Series I are specific crosses between chosen trees, and are alike from trial to trial. Generalizations are therefore more readily made. Data are available for seven of the eight Ghana trials; details of disease losses are shown in Table 28. The overall level of disease incidence varied considerably,

TABLE 28
Series II Trials 1960-61 season: incidence of pod diseases
(Percentage of diseased pods)

Trial	Varieties											
	A	B	C	D	E	F	G	H	J	K	L	M
Apedwa ...	—	—	15	16	—	8	—	7	6	12	13	8
Asikuma ...	4	4	—	2	6	3	—	4	4	—	3	—
Pankese ...	10	13	10	8	13	8	10	9	—	—	—	—
Fumso ...	11	—	15	19	16	9	18	9	—	16	—	—
Foso ...	3	3	4	1	5	2	2	2	—	—	—	—
Buaku ...	—	11	18	15	17	7	10	10	—	19	—	—
Akaa ...	0	0	1	—	0	0	—	2	—	0	—	—

being lighter on the trials which are bearing less heavily. This may be associated with the more open canopy of the slower growing plots as much as with the lesser crop.

It will be seen from Table 28 that variety F is relatively lightly infected, that H and J are also good, while E is most heavily attacked. Analysis of variance of the percentage losses on the varieties C, D, F and H in the heavier-bearing trials, Apedwa, Pankese, Fumso

and Buaku shows high significance, C and D being significantly more heavily infected than F ($P=0.01$) and H ($P=0.05$). Study of the losses at Buaku, Apedwa and Fumso shows variety K also to be significantly more heavily infected than H and F ($P=0.01$).

Rodent damage was light, but patterns were nonetheless detectable. Comparison of data from Buaku, Apedwa and Fumso shows the attack on Variety K to be significantly heavier than on C, D, F and H, while attack on Variety H was significantly lighter than on C or D. The data from all trials shows that variety G is especially heavily attacked. It would seem that those varieties which do not have some Parinari parentage (D, F, H, J) are less attacked than those which do.

STUDIES ON NATURAL POLLINATION

There is evidence that a substantial proportion of pollinations by flying insects involves pollen from more than one flower, and that the movement of pollinating insects is not entirely random, possibly being influenced by air-movement. (Glendinning, in press).

THE RELATIONSHIP BETWEEN GROWTH AND YIELD

Studies on the relationship between growth and yield in the 9th progeny trial (P.T.) have been published (Glendinning, *Euphytica* 1, 351-355, 1960). This trial was planted in 1954, and the yield up to 1959 was correlated with the stem diameters of the plants a few months after planting out, with the early growth rate in the field, and with the degree of reduction in the growth rate following the onset of bearing. Further studies have utilized the technique of correlating yield with two or more factors at the same time, and yields up to March 1961 have been incorporated. Very close correlations have been obtained, as shown in Table 29.

TABLE 29
Multiple correlation co-efficients (R) of yield with various growth factors

Factors:—	Accumulated Yield to March		
	1959	1960	1961
1. November 1954 diameter and growth-rate 1954-1957	0.959	0.946	0.926
2. As (1), but the difference between the growth-rates 1954 to 1957 and 1957 to 1959 incorporated in addition	0.965		
3. As (1), but the difference between growth-rates 1954 to 1957 and 1957 to 1960 incorporated in addition		0.948	
4. As (1), but the difference between growth-rates 1954 to 1957 and 1957 to 1961 incorporated in addition			0.929

It will be seen that the introduction of the third factor, *i.e.* the reduction in the growth rate following the commencement of bearing, has resulted in very little improvement in the relationships. It gave a very slight improvement in the correlation with yield up to March 1959, but virtually none in the others. This is because the reduction in growth rate is itself closely correlated with the 1954-57 growth rate. The significance of this reduction in growth rate as a factor influencing yield independently of the earlier growth rate is therefore now in doubt, and study of further trials is needed. It seems that the November 1954 stem diameters serve as a correction for differences in the date of sowing of the different varieties and for their initial size, in which case it may be that had the varieties all been alike in these respects yield would have been very closely correlated with early growth rate alone.

SELFING OF SELF-INCOMPATIBLE COCOA

A technique has been developed for self-fertilizing self-incompatible cocoa. It consists of pollinating flowers with a small quantity of their own pollen together with a much larger quantity of pollen from a tree compatible with the tree to be selfed. If the pollen from the second tree carries a dominant character that can be detected in the hybrid seedlings, selfed and hybrid seedlings can be separated. The 'axil spot' character was used in the experiment, and from some dozen attempts one pod was obtained which gave 46 seedlings with 'axil spot' and 4 without it. These 4 seedlings are therefore believed to be selfed progeny of the incompatible tree (Glendinning, *Nature, Lond.*, **187**, 170, 1960).

FAT CONTENT OF COCOA VARIETIES

A report on fat contents of eighteen varieties submitted to a British manufacturer, nine of which had Parinari in their parentage, showed that each of these nine varieties had a higher fat content than any of the others. Fat content as a percentage of the oven-dried nib ranged from 57.6 to 60.7 in varieties having Parinari in their parentage, being highest in F1 Nanay Parinari hybrids (60.7 and 60.5 per cent), while in varieties without the Parinari factor it ranged from 53.8 to 57.1, being lowest in Criollo and Trinitario types (53.8 to 56.4 per cent). Amelonado included in the series had 57 per cent fat.

Reports on quality of sample submitted to manufacturers' organizations in April 1960 are awaited.

SOIL FERTILITY, IRRIGATION AND SHADE

FIELD EXPERIMENTS (R. W. Smith)

Amelonado shade and fertilizer experiment (K1)

The yields have again been high, the unshaded cocoa with fertilizer producing 3,474 pounds of dry cocoa per acre, the highest yield of cocoa ever reported from W.A.C.R.I. The results, compared with those of previous years are presented in Tables 30 and 31.

The fertilizer response on unshaded cocoa has decreased this season but the expected decrease in the yield of the unshaded cocoa without fertilizer has not taken place. One third of the plot, a cross-section over the shade and fertilizer treatments, has been irrigated since January 1960. Table 31 shows the effects of irrigation, the

TABLE 30
Yields from the shade and fertilizer experiment
(lb. dry cocoa per acre)

	1957-8	1958-9	1959-60	1960-61*
Shade, no fertilizer ...	586	958	756	702
Shade, with fertilizer ...	849	1,211	906	969
No shade, no fertilizer ...	1,100	2,348	2,187	2,448
No shade, with fertilizer ...	1,602	3,091	3,088	3,474

* $\frac{1}{3}$ of the experiment received irrigation in 1960-61. These figures have been adjusted to represent the expected overall yield if irrigation had not been applied, and are directly comparable to the results of previous years.

TABLE 31
Yield following shade removal, addition of fertilizer, and irrigation
(expressed as per cent of control plot yield)

		1957-8	1958-9	1959-60	1960-61
Shade removal effects ...	With fertilizer ...	189	255	341	359
	Without fertilizer ...	188	245	289	349
Fertilizer application effects ...	With shade ...	145	126	120	138
	Without shade ...	146	132	141	142
Combined effects of shade removal and fertilizer application ...		273	323	408	495
Irrigation effects	Shade with fertilizer ...	-	-	-	119
	Shade without fertilizer ...	-	-	-	121
	No shade with fertilizer ...	-	-	-	109
	No shade without fertilizer ...	-	-	-	122
Combined effects of shade removal, fertilizer application and irrigation ...		-	-	-	539

present year's yields being compared with the pre-irrigation treatment yields of the previous season.

Fermentations of every harvest have been carried out throughout the season to determine the factor for converting the numbers of pods to weight of dry cocoa. The mean conversion factor from 184 fermentations is 11.94 pods per lb. of dry cocoa. There was no significant difference between treatments, nor between harvest dates. A conversion factor of 12 pods per lb. of dry cocoa has therefore been used throughout.

Factorial fertilizer experiments

In 1960-61 the results from the factorial experiments continued to demonstrate the response to phosphates and, to a lesser degree, to nitrogen. The experiments are as follows:

- A. Six 2² NP: KMg(Ca) factorial experiments in Ashanti.
- B. A 2⁴ NPKMg factorial experiment at Tafo. (G5).
- C. A 2⁴ NPKMg factorial experiment at Bunso.
- D. A 2⁴ NPKMg factorial experiment at Apedwa.
- E. A 2³ NPK factorial experiment at Bunso.

The results from these trials will be reported in more detail elsewhere.

Phosphate experiments

The first year's results from a series of experiments in Ashanti/Brong Ahafo are available but inconclusive. The treatment means are presented in Table 32.

TABLE 32

Phosphate Experiments

Yields (numbers of pods per plot), adjusted by analysis of covariance using two years' pre-treatment yields as the independent variate

Site					Dampong	Yawnso	Poano	Mabang
Treatment								
Control	...	...	...	...	150	460	177	279
NKMg	...	...	...	...	156	368	195	362
NKMg + 40 lb./acre P ₂ O ₅	...	...	...	...	126	507	202	373
NKMg + 80 lb./acre P ₂ O ₅	...	...	...	...	186	409	151	398

Site					Atwedie		Nkawie	
Treatment								
Control	...	...	...	...	147		462	
NKMg	...	...	...	...	224		551	
NKMg + Rock phosphate	...	...	...	...	196		500	
NKMg + Super-phosphate	...	...	...	...	218		632	

None of these differences is significant at the P=0.05 level.

WEST AFRICAN COCOA RESEARCH INSTITUTE

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ERRATA

P. 14. Table 1

Mean Relative Humidity 23-year Mean
(1500 G.M.T.) 1960.

	April	May	June	July	August
For	59.9	64.8	70.7	70.8	69.6
Read	62.8	67.9	73.9	73.9	72.5

Annual rainfall (in inches) 1938 to 1960
1956 For 61.12 Read 51.12

P. 65. Third paragraph, last line

For total—C Read organic C

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ences in response at four centres (Domiabdra, Obuasi, Antoakrom and Brofoyedru) where 2² NP, KMg factorial trials are being conducted. Data obtained so far showed that over 50 per cent of the total-P in almost all the soils was in the organic form. The amount of organic-P was highly correlated with the percentage of total-N, percentage of organic-C and the pH of both the 0-2 in. and 2-6 in. samples, and did not mineralize after incubation for 14 and 28 days at laboratory temperatures and 50 per cent water holding capacity. The importance of the phosphorus associated with the organic matter in these soils was supported further by the high correlation between the total-P and the percentage total-N and total-C.

Fractionation experiments on the 0-2 in. samples showed that the calcium-P in Antoakrom and Brofoyedru soils (cation exchange capacity, 25.20 and 20.00 m.e.; and 7.50 and 10.25 m.e. exchangeable Ca/100 g. soil respectively) tended to convert into aluminium-P and iron-P during incubation for 28 days, whereas the calcium-P in the Domiabdra and Obuasi (cation exchange capacity 50.10 and 35.40 m.e.; and 35.25 and 15.25 m.e. exchangeable Ca-100g. soil respectively) tended to increase.

The period of incubation is being extended and the effect of added nitrogen and phosphate on the mineralization is also being examined.

Effect of phosphate fertilizers

The effects of rock- and super-phosphate in trials at Atwere, Nkawie, Ashanti and W.A.C.R.I. Blocks H1 and L2 are being

followed by soil and leaf analyses. The first treatments—blank, basal (NKMg) and basal plus rock- or super-phosphate—were applied in April 1960. The first year's yields at Atwere and Nkawie showed increases of 27.1, 14.2, and 39.4 per cent for the basal, basal plus rock-phosphate and basal plus super-phosphate treatments respectively. Analyses of soil samples taken in November 1960 showed that phosphorus applied as rock-phosphate remained longer in the more soluble form of calcium-P whilst that of super-phosphate was converted largely into iron- and aluminium-P. The data further show that the phosphates, especially super-phosphate, had a suppressive effect on the uptake of iron, whilst the uptake of copper was slightly higher in the presence of super-phosphate. The uptake of the major nutrients appeared to be unaffected.

A comparative study of forest and cocoa soils at W.A.C.R.I.

Various soil series under secondary forest and cocoa are being examined for chemical and biological changes which occur when forest is clear-felled and cocoa grown. The constituents of soil organic matter (carbon, nitrogen, phosphorus and sulphur), and changes in the rate of nitrification and in the exchangeable potassium during the year, are being studied.

Fertilizers and litter

Field experiments have started to find out the effect on the growth of cocoa seedlings of broadcasting fertilizers on thick leaf litter. The following new treatments have been superimposed on the site of the former soil exposure experiment (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 60), bare soil, litter only, fertilizer only (100 lb. Nas urea, 100 lb. P_2O_5 as triple super-phosphate, 75 lb. K_2O as K_2SO_4 and 50 lb. MgO as $MgSO_4$ per acre) and litter plus fertilizers. To help interpret the results, laboratory experiments are being conducted to find out the chemical changes which take place on incubating leaf litter alone and leaf litter plus fertilizers, both with and without soil sampled from the same series near the site.

Pot experiment

A pot experiment using concrete tanks was commenced to compare the effects of different compounds of phosphorus (rock- and triple-superphosphate) and nitrogen (urea and sulphate of ammonia) and soil pH on the growth of, and uptake of native micro-nutrients by, young cocoa seedlings from three soils from Hwidiem, Mabang and Yawnso of pH 7.05, 6.35 and 5.80 respectively. Seedling height and leaf measurements are being taken.

Potassium deficiency on Amazon cocoa at Tafo (R. W. Smith, D. K. Acquaye, R. G. Lockard)

Ghana cocoa soils generally contain ample supplies of available potassium and usually give no response to potash application. A potassium deficiency on a cocoa soil is therefore of some interest.

Chlorotic and necrotic leaf symptoms, accompanied by defoliation, appeared, during the dry season of November 1960–March 1961, on Amazon cocoa in Block A6. The cocoa was planted in 1956 on clear-felled land under temporary shade of tree-cassava, and with several ground cover treatments (*Rep. W. Afr. Cocoa Res. Inst.*, 1958–59, p. 52). A 2² NP: KMg factorial trial was superimposed on the block two years after planting and the cocoa had grown well, producing approximately 200 lb. dry cocoa in the second year and 2,000 lb. in the fourth year. The deficiency symptoms were very mild where the KMg fertilizer treatment was applied and also on the plots that had been mulched with elephant grass, which is rich in potassium. Whereas no response was obtained with the KMg treatment in previous years a response occurred this year with the onset of deficiency symptoms (Table 33).

TABLE 33
Yields from Plot A6
(mean number of pods per plot)

<i>Fertilizer Treatment</i>	1959–60	1960–61
Control	309	399
N–P	424	474
K–Mg	366	510
NPKMg	463	585
L.S.D. at 5 per cent level	73	86
L.S.D. at 1 per cent level	100	119

Leaf analyses showed that the potassium content* of the newly matured leaves had reached a low level of 0.40–0.95 per cent as compared with a range of 1.5–2.5 per cent in normal trees as reported in the literature. The magnesium content in the leaves remained normal but the K/Mg ratios ranged from 0.47 to 1.64 per cent as compared with 3.00, 2.42 and 3.06 calculated from data by Murray, D. B. (*Imp. Coll. trop. Agric. Rep. Cacao Res.*, 1955–56, pp. 21–22), and Lockard, R. G. (*Minist. Agric. Fed. Malaya, Bull.* 107, 1959).

*Expressed on oven dry material.

Analyses of soils from the different plots showed a range of 0.037–0.116 m.e. exchangeable K/100g. soil as compared with a range of 0.18 to 0.82 m.e. in 1958. Pod analyses (husks 1.60–4.15 per cent K* and beans 0.80–1.30 per cent K*) showed that a considerable amount of potassium was being removed from all the plots; the concentration of potassium being higher in pods from the mulched plots and where potassium had been applied. The calculated annual removal of potassium ranged from 28–70 lb. per acre.

The literature suggests that in plant nutrition potassium availability is related to water supply. The transpiration rate of leaves from K-deficient plants usually is higher than from K-sufficient plants in sunshine but lower under cloudy condition. The symptoms of drought in cocoa leaves are somewhat similar to those developed under K-deficiency; the symptoms in this case occurred in the dry season. Accordingly an experiment involving artificial shading, watering, and the application of potassium as a foliar spray has been superimposed on the plots to find out more about the factors inducing the deficiency.

SHADE AND FERTILIZER EXPERIMENT (K1)—FOLIAR ANALYSIS (J. C. Burridge, R. G. Lockard, D. K. Acquaye)

Throughout the past year, leaf samples have been taken every four weeks from this experiment and some of the results of the chemical and spectrographic analyses are given below. The full statistical analysis of the extensive data awaits the return of the Statistician from leave.

Sampling

There are 36 plots each of 100 trees in this experiment with 9 replicates of the four main shade and fertilizer treatments. Alternative trees in all the 36 plots were tagged with paint and at each sampling time one of the recently matured leaves of the lower shaded part of the canopy was taken from every tagged tree. The leaves from each plot were combined, dried at 80°C. and finely ground in a hammer mill before analysis. This method of leaf sampling ensured that the sub-samples used for laboratory analysis would be representative of the plots, and although it might have been preferable to use leaves from the more active upper part of the canopy, this was precluded by practical difficulties. To obtain information on seasonal variations of the mineral contents of the leaves, samples from all the plots were taken at four-weekly intervals from February 1960 to March 1961. It is planned to continue collecting samples from this experiment for at least two more years, but at eight-weekly intervals.

*Expressed on oven dry material.

Methods of laboratory analysis

Nitrogen, phosphorus, potassium, calcium and magnesium were determined by standard methods of chemical analysis; micro-kjeldahl for N, molybdenum-blue for P, flame-photometer for K, versenate titration for Ca and Mg. The method of phosphorus analysis described by Fogg and Wilkinson (*Analyst*, **83**, 406, 1958), in which ascorbic acid is used as reducing agent, was adapted for plant material and has proved highly satisfactory under tropical conditions. Spectrographic determinations were also made for copper, iron and manganese by a method based on that of Farmer (*Spectrochim. Acta*, **4**, 224, 1950), but palladium instead of chromium was used as internal standard for iron and manganese. Microphotometric measurements were made on the following lines: Cu 3273.96, (Ag 3280.68 as internal standard) Fe 3020.64, Mn 4034.49 (Pd 3404.58 and 3634.70 as internal standard).

Results

Chemical analyses were made on every sample (36 plots at 15 sampling times), and the mean values over the whole experiment are plotted against time in Figures 6 and 7. Spectrographic analyses were made on bulked samples obtained by combining the samples taken from three plots (e.g. plots 1, 25 and 28) on three consecutive sampling dates. This provided three replicates of each of the four main treatments at four different sampling times, each extending over three months. These data are summarized in Table 34. Attention will be drawn only to the more important results indicated by the Figures and Table. A full discussion cannot be made until data have been collected over several seasons.

Macro-nutrients

Although considerable differences exist between the four shade/fertilizer treatments, a detailed statistical analysis must be made before they can be properly assessed. However, the means for the experiment as a whole have revealed some very interesting seasonal changes in leaf composition. Apart from the well known similarity of the trends of nitrogen and phosphorus, two features of Figure 6 are noteworthy. Firstly, the leaf concentrations of these two elements appear to be considerably lowered during the development of the main crop; secondly the phosphorus concentration declined nearly three months before that of nitrogen. A possible explanation for this latter effect may be that the soil is well supplied with available nitrogen (particularly at the transition between dry and wet seasons), but that it is low in phosphorus. Although the phosphorus concen-

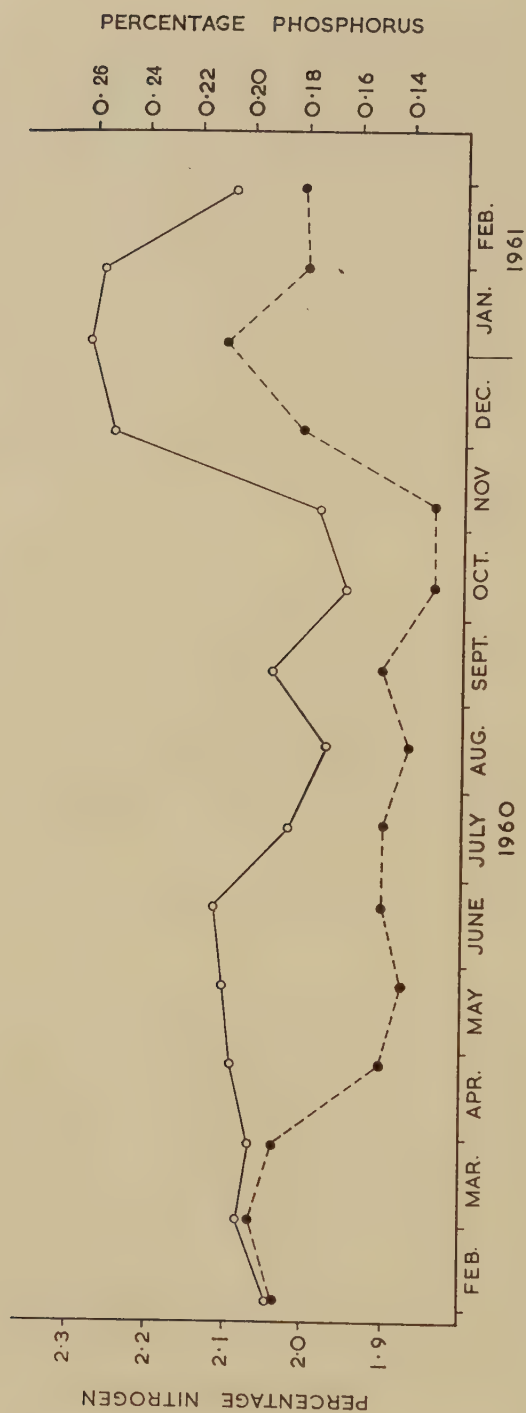


FIGURE 6. Leaf concentrations of nitrogen (solid line) and phosphorus (broken line) from 3rd February 1960 to 28th February 1961 (on oven-dry basis) in shade and manurial experiment.

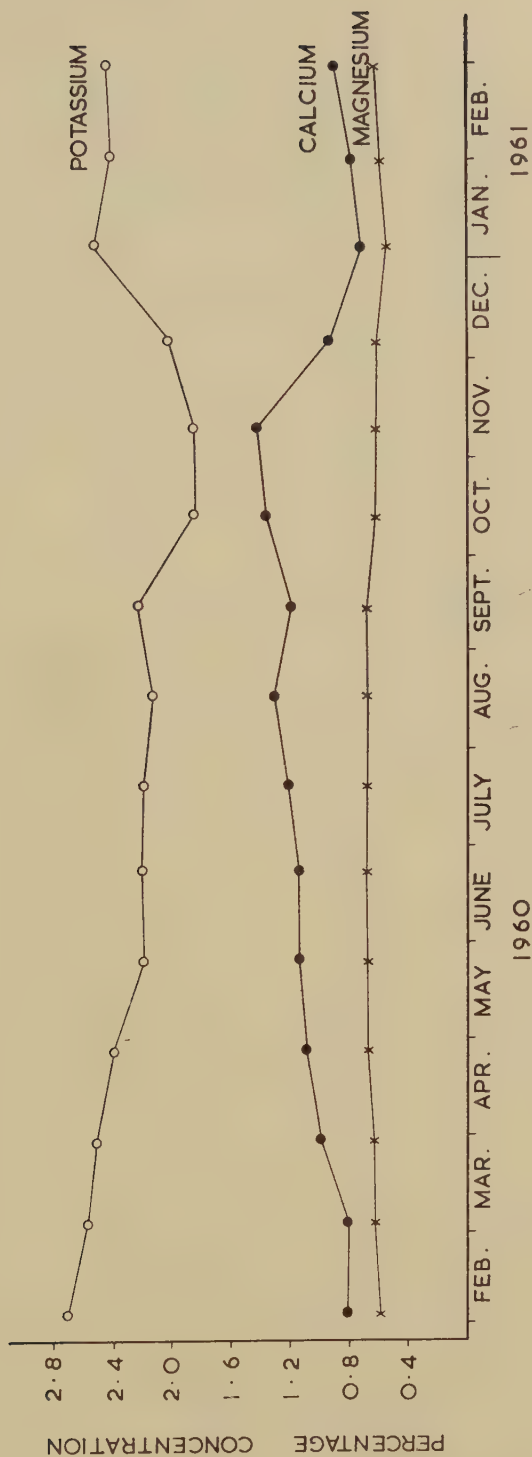


Figure 7. Leaf concentrations of potassium, calcium and magnesium (on oven-dry basis) in shade and manurial experiment.

TABLE 34
Concentrations of Copper, Iron and Manganese in oven-dry leaf material (ppm)*

Sampling dates	No shade-no fertilizer				No shade-fertilizer				Shade-no fertilizer				Shade-fertilizer			
	Cu	Fe	Mn		Cu	Fe	Mn		Cu	Fe	Mn		Cu	Fe	Mn	
A 3/2/60 to 30/3/60	8.7	73	153		7.4	84	198		7.9	73	128		9.1	81	192	
B 26/4/60 to 21/6/60	7.6	99	223		8.0	116	271		8.1	106	192		9.6	124	291	
C 19/7/60 to 13/9/60	6.3	80	197		5.8	113	254		6.6	78	175		6.8	88	252	
D 11/10/60 to 6/12/60	6.1	68	183		6.9	123	286		10.2	108	226		11.6	109	276	

* All values shown in the table are the means of three samples, every sample being bulked from 3 plots over 3 sampling dates.

tration in the leaves reached very low levels, no symptoms of phosphorus deficiency were found.

Figure 7 gives the concentrations of potassium, calcium and magnesium throughout the year and shows firstly, the very marked drop in the potassium level which reflects the large requirement of the trees for this element when the pods are developing and ripening. Secondly the interaction of potassium and calcium is striking; as the level of potassium decreases, so the calcium level increases and the two curves are almost mirror-images of each other. This relation is well known for many plant species but it had not been previously demonstrated with cocoa at Tafo; thirdly the concentration of magnesium is almost constant throughout the whole year, although there is a slight tendency for the magnesium level to parallel the calcium level.

Micro-nutrients

The leaf concentrations of copper, iron and manganese are shown in Table 34.

Statistical analysis of the analytical data has shown that the application of fertilizer on this trial has significantly increased the leaf contents of iron ($P=0.01$) and manganese ($P=0.001$) but has not affected the copper contents. The slight reduction of soil pH from 6.8 to 6.4, which has occurred in the 0-2 in. layer on those plots that have received fertilizer, could explain the increased uptake of iron and manganese.

The copper content of leaves from the unshaded plots was significantly lower than in the shaded plots ($P=0.01$) but there was no significant shade effect on the iron or manganese concentrations. It is possible that the lower copper contents have been caused by the much higher (about 3.5 times as great) yields of the unshaded plots (cf. Table 30). The amount of copper in the beans from these high yielding plots probably represents a much larger proportion of that available in the soil than do the amounts of iron and manganese.

FERTILIZER RECOMMENDATIONS TO GHANA FARMERS

In response to interest by farmers and commercial firms, W.A.C.R.I., in conjunction with the Cocoa Division of the Ministry of Agriculture, has made an interim recommendation of 1 cwt. Urea and $1\frac{1}{2}$ cwt. of triple superphosphate per acre per year. This recommendation is only a temporary one pending further results from field experiments.

COCOA PREPARATION AND QUALITY

(H. W. S. Allison and R. H. Kenten)

LARGE-SCALE PROCESSING OF COCOA

Assessment results

Samples of approved Amazon cocoa from stacked tray and heap fermentations of six day duration together with Amelonado cocoa from heap fermentations of four and six days duration have been factory processed and assessed by the Cocoa Scientific Advisory Committee of the United Kingdom (C.S.A.C.). All these samples were found to be within the West African flavour range. The C.S.A.C. stated that the Amazon samples fermented by the heap method were slightly inferior to those fermented by the tray method.

Fermentations of different duration were made with Amelonado and mixed approved Amazon varieties during the major and minor crop using the tray and heap methods. Single and double tray fermentations of Amelonado cocoa from the major and minor crops were also made. Samples of all these fermentations have been sent to the C.S.A.C. for factory processing and assessment.

Sun-drying

This year's experience confirms our previous report that drying in the tray in a two-inch layer is not always satisfactory during wet weather because this can lead to the development of internal mould. Drying in a one-inch layer has again proved satisfactory. Consequently, when the weather is unfavourable, the proportion of the fermenting mass to the drying area of the tray needs to be adjusted (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 67).

Mechanical drying

Mechanical drying was started at the end of October and 23 tons dry cocoa was processed. The results suggest that it will be possible to produce 1 ton dry cocoa with a fuel consumption of less than 40 gallons of diesel fuel. Some difficulty has been experienced with broken beans and brittle shell. This may be due to slightly over-drying although the speed of drying and methods of raking may be partially responsible. This problem will be investigated during the next crop.

STATISTICS

(C. de Jonge)

Many complications peculiar to the cocoa crop require the use of special statistical techniques. Work on the theoretical development of these methods has continued and one has been found for applying

a valid F test to early harvest data; full details will soon be published. Advances have also been made towards simultaneous lateral allowance in calibrated analysis. The designs used in experiments have proved to be satisfactory and certain adaptations from the standard methods which have been developed recently will be tested soon.

The computing room has been completed and a number of assistants have been employed and trained to do standard types of analysis using the electric computing equipment.

IBADAN STATION

VIRUS RESEARCH

VECTORS OF NIGERIAN COCOA VIRUSES (C. K. H. Martini)

Soil samples from the only known outbreak of cocoa necrosis virus (CNV) at Omi Aboderin contained migratory soil nematodes. Two species of *Xiphinema* seemed more numerous in samples taken close to infected trees than in samples from uninfected trees. This and the fact that the spread of CNV is far more restricted than that of cocoa swollen shoot virus (CSSV) suggested that it might be transmitted by nematodes. A number of transmission experiments have been done in cooperation with Dr F. E. Caveness of the United States I.C.A./I.D.S. Mission to Western Nigeria but no symptoms have been seen on any of the plant species tested.

In attempts to transmit CNV mechanically by inoculating a wide range of test plants with concentrated extracts from infected cocoa leaves only *Adansonia digitata* L. showed obvious signs of a virus infection. The veins of infected leaves had several flecks of 2-3 mm. length surrounded by transparent haloes. These symptoms occurred on at least four subsequently-formed leaves and later on occasional leaves. When infected seedlings were cut back the sequence of symptom development was repeated on developing auxiliary shoots. This disease was transmitted to other *A. digitata* seedlings by mealybugs. Some transmissions were also obtained from cocoa seedlings infected with CNV. The isolate originated from a tree that was not fully invaded but apparently recently infected. Later attempts to transmit the virus from cocoa to *A. digitata* have however failed. Back tests from *A. digitata* seedlings to cocoa have been done but because no symptoms have yet appeared it is uncertain whether the transmitted disease is CNV.

The isolates of CSSV from Ajia and Offa Igbo (No. 159) have again been transmitted by *Aphis gossypii* Glover. (*Rep. W. Afr. Cocoa*

Res. Inst., 1959-60, p. 69) at the rate of 5-12 per cent when cocoa half-beans were infested with 50 aphids that had fed on soft flush leaves of recently infected cocoa seedlings. Four other isolates of CSSV, one isolate of cocoa mottle leaf virus and two isolates of CNV were not transmitted under these conditions. The isolates from Ajia, which causes a mild disease, and that from Offa Igbo (No. 159), which causes a severe disease, were, at the time when the transmission by aphids was studied, more readily transmitted by mealybugs than any of the other isolates of CSSV. Transmissions have only been obtained when at least 150 aphids were made to feed on an area of 20 mm. diameter. Plants infected by aphids were no better sources for further transmission by aphids than mealybug-infected plants, and mealybugs transmitted the virus from them as readily as from sources infected by mealybugs. Attempts to transmit the isolates Ajia and Offa Igbo (No. 159) from *A. digitata* have failed. Single *A. gossypii* feed readily even on old leaves of *A. digitata* but not in dense colonies and this might be a reason for the failure. It has been suggested that winged *A. gossypii* might account for much of the spread of CSSV over long distances. The experimental results do not support this view. Firstly, only few isolates seem to be transmitted by aphids and then only after frequent passages through young cocoa seedlings when they become also more readily transmissible by mealybugs. Secondly, *A. gossypii* occurs on cocoa only rarely and then in small colonies.

EXTRACTION OF NIGERIAN COCOA VIRUSES (C. K. H. Martini)

Only during the latter part of the period under review has a reliable method for the extraction of cocoa viruses been found. Leaves are now infiltrated (Brunt & Kenten, *Virology*, **12**, 328, 1960) with buffer of high molarity and then ground in distilled water or weak buffer. Extracts are then clarified and concentrated by differential centrifugation. Source material is produced by infesting cocoa half-beans or cotyledons of *A. digitata* seedlings with 35 mealybugs each to ensure the development of severe symptoms. Severely affected leaves are more rapidly infiltrated than leaves with mild or no symptoms and possibly have a high virus content. The infectivity of extracts is at present demonstrated by inoculating young seedlings of *A. digitata*. These produce preliminary symptoms after 12-14 days, while all other plants, including cocoa, tested so far take a much longer time. Temporarily, quantitative assessments of infectivity have been made by diluting concentrated extracts until less than 100 per cent of the test plants became infected. This, however, was later found to be impracticable as at high dilutions inconspicuous

symptoms tended to develop many weeks after inoculation. The presence of a penetrating agent during infiltration and a tannin absorbent during grinding seem to be essential. The addition of a reducing agent to the infiltrating buffer delays or prevents the oxidative browning which makes extracts more difficult to clarify but not uninfected. Out of a number of reducing agents tested only ascorbic acid, L-cysteine (Brunt & Kenten, *l.c.*) and sodium sulphite were of use. Other additives, e.g. phenol-oxidase inhibitors, do not appear to increase the infectivity of extracts made in large volumes of water.

It is not yet known why the extraction method outlined is more reliable than others that have yielded infective preparations rather irregularly. Certain details, e.g. the optimal strength of the infiltrating buffer, are still to be investigated and the present set of conditions may have to be changed when more experience has been gained.

A NEW OUTBREAK OF VIRUS IN NIGERIA

(T. W. Tinsley and J. F. Longworth)

Until recently it was thought that the Ondo Province in the east of the Western Region was free from swollen shoot disease. Intensive control measures had been adopted to prevent the virus spreading from the Area of Mass Infection around Ibadan. An inspection party of the Cocoa Survey Division of the Ministry of Agriculture and Natural Resources, Western Region of Nigeria, has discovered an outbreak comprising some two thousand trees near Owena, on the Ondo Province. The data on rates of spread of cocoa viruses in Nigeria suggests that this outbreak has existed for almost a decade.

The cocoa was mature randomly planted Amelonado and the healthy cocoa in the vicinity was in good condition. Many of the infected trees were moribund and this virus must be considered to be at least as virulent as others in Nigeria. There was little evidence of recent mirid damage and this cannot be considered as a contributing factor.

The symptoms on the mature trees were pronounced red banding along the veins of young leaves with intensive chlorosis and diffuse vein clearings on the hardened leaves. Swellings were observed on fan branches and chupons. Pods were often rounded and frequently showed distinct red or yellow mottling. This type of mottle is not usual for Nigerian cocoa viruses. Extensive collections of infected material have been made and detailed observation will be made in cocoa grown uniformly in the laboratory. It will be several months before these records are complete so that the origin and relationships of this virus are not yet known.

THE EFFECT OF ENVIRONMENT ON VIRUS-INFECTED COCOA

(J. F. Longworth)

This experiment at Alakia consists of five replications of four treatments:—

- A. A sward of *Panicum maximum*.
- B. Natural regeneration of weed growth.
- C. *Panicum maximum* mulch on bare soil.
- D. Bare soil.

The main plots were divided into four sub-plots, each containing twenty seedlings, and these comprised a 2² factorial layout of virus inoculation versus no inoculation and fertilizer applications versus none. Three replicates were planted with seedlings of an Amelonado-Trinitario hybrid and two with seedling progeny of open pollinated F₂ Amazon cocoa. The experiment was planted in June 1959 on clear-felled land. The soil type was chiefly of the Olorunda series and was considered by the Soils and Chemistry Division of the Ministry of Agriculture and Natural Resources, Western Region, as suitable for cocoa. Ground covers were applied at time of planting, and the area was shaded with a palm-frond canopy during the first dry season. Fertilizer was applied in September and March, and virus inoculations were made in March 1960.

The growth of seedlings in mulch and bare soil plots was superior to that under living ground covers. Virus infection reduced flushing in both Amazon and Amelonado-Trinitario hybrid cocoa (Table 35), but fertilizer applications checked this reduction in Amazon seedlings. In fact, in the Amazon seedlings fertilizer increased flushing,

TABLE 35
Total number of flushes from June to October 1960

(a) <i>In ground cover treatments</i>				
	A	B	C	D
F ₂ Amazon	2,213	1,393	2,421	2,324
Amelonado/Trinitario hybrids	2,253	1,317	2,561	2,076
Total	4,466	2,910	4,982	4,400

(b) <i>In virus-fertilizer treatments</i>				
	<i>Virus + fertilizer</i>	<i>Virus</i>	<i>Fertilizer</i>	<i>Control</i>
F ₂ Amazon	2,162	1,538	2,582	2,072
Amelonado/Trinitario hybrids	1,972	1,804	2,235	2,396
Total	4,134	3,342	4,817	4,468

though no increase in flushing was observed in the manured Amelonado-Trinitario hybrid seedlings.

The superior growth in the mulch and bare soil treatments is reflected in the number of plants which produced jorquettes. By May 1960, 73 per cent and 69 per cent had formed jorquettes in treatments C and D, and 61 per cent and 50 per cent in treatments A and B.

In the treatments producing most vigorous growth there was more rapid expression of symptoms of virus infection (Table 36).

TABLE 36
Symptom expression (per cent) in the ground cover treatments in June and July 1960

				A	B	C	D	Mean
<i>June</i>								
F ₂ Amazon	...	...	...	39.2	57.1	60.2	47.2	49.8
Amelonado/Trinitario hybrid	...	...	...	41.5	49.5	51.3	59.2	50.2
Mean	...	...	...	40.6	52.7	52.9	54.4	50.0
<i>July</i>								
F ₂ Amazon	...	...	...	59.4	68.8	78.2	73.6	70.1
Amelonado/Trinitario hybrid	...	...	...	74.6	69.7	77.9	82.4	76.1
Mean	...	...	...	68.7	69.4	78.0	78.9	73.7

In both Amazon and Amelonado-Trinitario hybrid replicates, more seedlings with symptoms were observed in the mulch and bare soil treatments.

Analysis of the increment in stem diameter from February to November 1960 showed significant differences between the ground cover treatments. The reduction in stem diameter caused by virus infection was also significant. There was 10 per cent response to fertilizer in Amazon plots, which was not significant.

The 1960-61 dry season was particularly severe, and was unusual in that severe 'Harmattan' conditions began in November. No more than 0.75 in. of rain fell between November and March and considerable differences in survival were observed between treatments, compared with the first dry season when the area had been shaded and losses were negligible. Many seedlings died in the living cover treatments, and losses were negligible in mulch and bare soil. The greater survival in the latter treatments may have been assisted by the fact that a complete canopy had been formed as a result of early jorquette formation (Table 37).

TABLE 37

Number of plants surviving in February 1961, in virus-infected and manured plots under the four ground covers

	<i>Virus + fertilizer</i>	<i>Virus</i>	<i>Fertilizer</i>	<i>Control</i>	<i>Total</i>
A	71	71	77	80	299
B	55	47	82	69	253
C	96	95	87	92	370
D	91	88	91	91	361
<i>Total</i>	313	301	337	332	1,283

Virus infection reduced the survival of the seedlings ($P=0.05$) and there was a significant interaction between virus infection and ground cover ($P=0.01$), which was largely due to the effect of virus on Amelonado cocoa. The interaction between virus and variety was also significant and virus infection reduced survival in the natural regeneration and *Panicum maximum* cover treatments. Fewer plants survived in the latter treatments (Table 37), largely as a result of considerable losses in one Amelonado-Trinitario hybrid replicate in each of these treatments.

Analysis of total stem diameter in February 1961 showed a significant difference between the two cocoa types ($P=0.05$). Stem diameters in treatments C and D were greater than those in A and B ($P=0.01$) and were smallest in treatment B.

Virus infection caused a significant reduction in stem diameter of Amelonado-Trinitario hybrid cocoa ($P=0.001$), but not that of Amazon cocoa. The Amazon cocoa responded significantly to fertilizer ($P=0.05$) and this response was mainly produced by the non-infected Amazon cocoa but there were indications that fertilizer applications produced some response on virus infected Amazon and Amelonado-Trinitario hybrid cocoa.

The results of this experiment afford a comparison with those obtained by Cunningham and Smith (*Trop. Agric. Trin.*, **38**, 13-22, 1961) in Ghana, who showed that both grass mulch and bare soil were superior to grass cover and natural regeneration in growth of Amazon cocoa in the first dry season. There were no differences in survival between these treatments (R. W. Smith, personal communication). The rainfall data quoted by these authors show that appreciable amounts of rain fell in December and February and only January could be considered a 'dry' month. By comparison, in the present experiment the dry season extended for four months and the greater survival in mulch and bare soil treatments was of practical

importance. There are disadvantages of maintaining bare soil. Cunningham and Smith (*loc. cit.*) concluded that mulching young cocoa may prove uneconomic but this may not be so in Nigeria, where establishment is not merely a question of obtaining improved growth, but often of keeping the plants alive. The problems of establishment are of importance in the Western Region of Nigeria where replanting is being attempted on old cocoa soils. An account of methods of establishment is being prepared for publication.

The effects of virus under these conditions tends to substantiate the hypothesis for the decline of virus infected cocoa suggested by Kay, Longworth and Thresh (*VIII Inter-American Cacao Conf. Trin.*, 1960). There was a considerable effect of virus on growth of the Amelonado seedlings under the rather extreme conditions in treatments A and B, as a result of competition for water and nutrients afforded by the vegetation. There was a marked level of tolerance in the Amazon population; no effect of virus was observed on stem diameter or survival. Fertilizer applications checked the reduction of flushing in Amazon cocoa caused by virus infection. This response to fertilizer by Amazon cocoa and the lack of response in Amelonado are consistent with the negative results in many previous fertilizer trials on Amelonado cocoa in Ghana and Nigeria and the difference deserves further attention.

ENTOMOLOGY

(P. F. Entwistle)

SHOT-HOLE BORERS

Gallery development and breeding in cocoa

The proportion of galleries made by *Xyleborus morstatti* Hag. in cocoa in which breeding takes place appears to be very small. Observations have been made at five sites in Ibadan province, from which 310 galleries were examined. Brood chambers were present in only 15 of these and breeding had occurred in only one. In many instances the galleries were not developed beyond the initial entry hole and, when scored in terms of development the mean score for these was approximately 35 per cent of that awarded to a fully developed gallery with breeding. Copious exudations of mucilage from attacked cocoa plants may drive away some of the beetles but in seedlings which were watered once every two weeks, and from which there was no visible sap escape, the degree of gallery development was not noticeably different from that in more liberally watered plants, which exuded sap.

Relationship between intensity of attack and a source of infestation

Although *X. morstatti* attacks cocoa from September until March, breeding on this host is so infrequent that infestation probably arises from other sources. The wild host plants are not known but Robusta coffee (*Coffea canephora*), which is widely cultivated in small patches in Western Nigeria, is a favoured cultivated host. In view of this, cocoa seedlings were placed in three lines, each 700 feet long, extending from a plot of infested coffee. Attacks on these seedlings were found to be most numerous up to about 200 feet from the coffee. In two of the lines, running through cocoa, attack was virtually absent after 300 feet while in the line running through forest it remained at a fairly low level suggesting that some of the beetles were coming from wild hosts, but that the coffee formed the main source of infestation.

Effects of shade on levels of infestation

Table 38 summarizes the distribution of attacks in three experimental areas in which a comparison was made of the effects of shade and no shade. In each shaded plot cut fronds of oil palm were supported at six feet above the ground on bamboo poles.

TABLE 38

Numbers of attacks by X. morstatti in equal numbers of shaded and unshaded cocoa seedlings in each of three different areas

Area	Shaded		Unshaded		Totals	
	No. of plants	No. of attacks	No. of plants	No. of attacks	No. of plants	No. of attacks
Gambari SHB I...	1,120	103	1,120	16	2,240	119
Gambari SHB II	880	7	880	2	1,760	9
Alakia IV ...	720	1,564	720	68	1,440	1,632
Totals ...	2,720	1,674 (95.1%)	2,720	86 (4.9%)	5,440	1,760 (100%)

It is clear from this that *X. morstatti* shows a preference for shaded plants, but in view of the fact that in all three areas the nature of the shade was similar the possibility that this type of shade was an attractant cannot be ignored; (nor is it possible to dissociate the effects of shade on microclimatic factors such as temperature and humidity).

The effects of cultural conditions on incidence of borer damage

At Alakia I, planted in July 1959, four main treatments were each applied to two blocks of Amazon seedlings and three blocks of

Amelonado seedlings planted beneath palm frond shade. The treatments were:—

- A. Vigorous grass growth.
- B. Natural weed regeneration.
- C. Overall grass mulch.
- D. Bare soil.

In addition all plots were split for the application of fertilizer (an NPK mixture). Table 39 shows the distribution of attacks towards the end of the shot-hole borer season (March 1960).

TABLE 39

Total numbers of attacks by X. morstatti on Amazon and Amelonado varieties of seedling cocoa under eight different cultural treatments at Alakia I.

<i>Treatment</i>	<i>Amazon</i>		<i>Amelonado</i>		<i>Amazon + Amelonado</i>	
	<i>Fertilizer</i>	<i>None</i>	<i>Fertilizer</i>	<i>None</i>	<i>Fertilizer</i>	<i>None</i>
A	42.0	58.0	43.0	45.3	85.0	103.3
B	50.5	44.5	43.3	50.3	93.8	94.8
A+B	92.5	102.5	86.3	95.6	178.8	198.1
C	19.5	33.0	23.0	25.0	42.5	58.0
D	25.5	29.0	21.6	30.3	47.1	59.3
C+D	45.0	62.0	44.6	55.3	89.6	117.3
A+B+C+D ...	137.5	164.5	130.9	150.9	268.4	315.4

(Numbers of attacks have been corrected for different numbers of Amazon and Amelonado plants).

Analysis of these data indicated that significantly less plants were attacked ($P=0.05$) in the mulched and bare soil plots (C and D) than in those with a growing ground cover (A and B). The data also suggests that the application of fertilizer renders plants slightly less susceptible. It will be noted that Table 39 shows little difference in intensity of attack between Amazon and Amelonado seedlings.

In the Gambari Shot-Hole Borer Experiment I, ground treatments were either overall grass mulch or natural weed regeneration and, beneath the shade, plants associated with weed regeneration were again more heavily attacked than those with mulch. The plots were split for water (2 gallons per plant per week throughout the dry season) and no-watering. In both mulched plots and plots with weed regeneration, borer infestation was slightly higher where watering took place.

Seedling height and stem diameter in relation to attack

From the limited data available it would appear that attacks are concentrated on stems of between 0.5 and 0.9 cm. diameter. The

distribution about the mean of the basal girth of attacked plants was significantly different from that of unattacked plants (P varied from 0.10 to 0.025 in different experiments). Due to the restricted girth range of the experimental seedlings, however this point requires confirming.

Effects of attack on cocoa seedlings

Table 40 summarizes the effects of attack on mean leaf numbers of seedlings in four plots in three different areas in the Western Region of Nigeria.

TABLE 40

Effects of attack by X. morstatti on leaf numbers of seedlings during their first year in the field

Locality	Date	Mean leaf numbers		Variety
		Plants attacked	Plants not attacked	
Alakia I A+B	1/3/60	9.91	10.08	Amelonado
Alakia I C+D	1/3/60	23.59	22.54	Amelonado
Alakia I A+B	1/3/60	11.73	15.66	Amazon
Alakia I C+D	1/3/60	23.66	30.98	Amazon
Alakia IV	7/2/61	9.32	8.33	Amazon
Alakia IV	13/3/61	13.22	12.79	Amazon
Gambari SHB I	4/2/61	17.18	20.90	Amazon
Gambari SHB I	7/3/61	14.93	16.27	Amazon
Araromi	27/2/61	7.31	6.44	Amazon

(With the exceptions of Alakia IV which was not shaded and Araromi, which was under natural shade, all areas were under artificial shade.)

In only one area (Alakia I, Amazon A+B) did the attacked plants have significantly less leaves than the unattacked plants. Elsewhere, differences were negligible and in some instances attacked plants were more leafy than unattacked ones. At Alakia I, where observations continued into the beginning of the wet season in April 1960, a similar rate of recovery in leaf numbers of attacked and unattacked plants was noted with the advent of rainy weather.

At Araromi, planted beneath shade, there was no appreciable difference between leaflessness in the attacked and the unattacked plants (25.6 and 26.7 per cent respectively).

In no plot was there any association between shot-hole borer attack and death of seedlings. Of the 182 plants which had died by March 1961 in Gambari SHB I, 10 were on shaded plots and the remainder were unshaded. Death and attack occurred together in only one plant which was in an unshaded area. At Araromi the percentage of dead attacked and of dead unattacked plants was very similar (7.3 and 6.4 per cent respectively).

At Alakia I, where records of jorquetting were taken, it was found that attacked plants were delayed slightly as compared with un-attacked plants but when the wet season began in April 1960, differences between the two soon disappeared.

The conclusion to be drawn from the above data is that within the limits of the observed infestation levels, the effects of attack were negligible. In no instance was attack correlated with either death or leaflessness. The only detectable effects were a reduction of mean leaf numbers and delay in the formation of a jorquette; both these were slight and of short duration.

MINOR PESTS OF COCOA

Psychidae

After approximately fortnightly spraying at Alakia with *gamma*-BHC, dieldrin, Rogor or Malathion (or mixtures of two or more of these), the only arthropod pests constantly present were larval Psychidae (Lepidoptera) and spider mites *Tetranychus* sp. (probably undescribed).

During the year at least nine species of Psychidae have been found feeding on cocoa in Western Nigeria. So far only four of these have been definitely identified (by M. Jean Bourgogne of the Musée National d'Histoire Naturelle, Paris) namely:

Eumeta rougeoti Bourgogne

E. cervina Druce

Kotochalia junodi (Hael.)

Acanthopsyche sierricola (White)

The first two of these bear cases ornamented with lengths of twig arranged longitudinally: *E. cervina* is the larger, the cases of fully grown male larvae being about 5.6 cm. long and of the female larvae 9.0 cm. long, whilst those of male and female *E. rougeoti* are, respectively, 4.5 and 5.3 cm. long.

K. junodi is the wattle bagworm of South Africa, and has a case ornamented with irregular pieces of leaf. *A. sierricola* also has a case of leaves very similar to that of the former species, from which it can be distinguished by the close felt of short spines or fibres, usually most evident at the posterior end; these fibres are the remnants of the first instar case covering.

The most frequent and generally distributed species on cocoa are *E. rougeoti* and *K. junodi*, both of which also attack cocoa in Ghana, and to a lesser extent *A. sierricola*, not yet known from cocoa in Ghana.

The adult female is degenerate and distribution is effected in the first larval instar by aerial dispersion on 'parachutes' of silk; as an

adjunct to survival it is not surprising that polyphagy goes hand in hand with this haphazard habit. Most of the species have been shown to be present on a wide variety of other host plants, both cultivated and wild.

Observations on the life history, case-building habits, feeding behaviour and parasitism have been made and written up for publication elsewhere.

The means by which Psychidae escape the effects of contact and systematic insecticides is not fully understood. Initially the effect was thought to be more apparent than real as it was suspected that their continued presence might be due to the immigration of fresh larvae from surrounding areas. However, in November 1960, 16 psychid larvae were tethered to cocoa seedlings, with lengths of fine iron wire, in a plot scheduled to be sprayed with Rogor on the following day; at the same time 15 similar larvae were secured in a nearby plot not due for spraying. Four days after spraying the larvae were collected from the field and brought to the laboratory for examination. All were in good condition and, except for those that succumbed to parasites, they continued to feed and to develop in captivity. It was apparent that Rogor had had no effect.

With the adults, immunity is clearly of a physical nature; the adult female does not leave her larval case before the completion of oviposition, whilst the adult male usually has no contact with the host plant when it emerges. Shortly after emergence he flies to the female, mates and usually dies the same day. With the larvae the fact that they are able to survive long periods of starvation successfully may be relevant, in conjunction with the protection provided by their cases. But whatever the mechanism of protection may be, the presence of such resistant species on cocoa, coupled with associated parasites which are probably more susceptible, is a potentially dangerous situation. It is basically similar to that reported in the previous Annual Report for various wood-boring insects at Oyoko and Tafo in Ghana.

Cerambycidae

Extensive collections of *Tragocephala*, in the Western Region of Nigeria, have so far revealed the presence of only one species attacking cocoa. This is *Tragocephala nobilis* F. var *gorilla* Thoms. (*Rep. W. Afr. Cocoa Res. Inst.*, 1958-59, p. 34) which tends to occur more frequently than does its counterpart v. *castania* Thoms. on cocoa in Ghana. However, there is a single record of *T. nobilis* F. var *bassamensis* Thoms. bred from a larva found attacking cocoa at Ibadan (Mr H. Caswell, Faculty of Agriculture, University College of Nigeria).

Typical *T. nobilis* F., a form widely distributed throughout West Africa and found breeding on cocoa in Ghana and the Ivory Coast, was not seen during the past year in Nigeria.

During September 1960, adults of *Phosphorus virescens* Oll., whose principal host plants in Nigeria is cultivated *Cola*, were frequently found feeding on the bark of young cocoa stems especially those of seedlings. This species is not known to breed on cocoa in Nigeria though it does so in the Cameroons.

Alternative host plants of T. nobilis v. gorilla: In addition to cocoa, *T. nobilis* var *gorilla* has been found attacking a variety of wild host plants in Western Nigeria. *Solanum verbascifolium* L., a common weed of cultivation, appears to be most favoured but *Albizia zygia* Macbride, *Allophylus africanus* P. de Beauv., *Alchornea laxiflora* (Benth.) Pax & K. Hoffm., *Microglossa pyrifolia* Oliv. & Hiern., *Dahlbergia lactea* Voitse, *Diospyros monbuttensis* Gürke and a woody variety of *Hibiscus esculentus* L. (okra) have also been recorded during the year.

Biology: This is very similar to that already reported for *T. nobilis* var *castnia* in Ghana (*Rep. W. Afr. Cocoa Res. Inst.*, 1958-59, p. 35). The breeding technique employed for *castnia* was not wholly suited to *gorilla*: adults of the latter would not mate in lamp glass cages and had to be transferred to wooden cages large enough to contain potted seedlings of a size suitable for oviposition. As with *castnia*, the act of mating triggers the ring-barking behaviour which was very seldom noted in virgin females.

Field observations showed that only larvae were present in January, that pupation was beginning towards the end of February and that the first adults were emerging in early March. Freshly ring-barked stems containing eggs were first found on the 22nd of March 1960, and taking into account the incubation period, it is estimated that the first eggs were laid at the end of first week in March. The period of adult emergence was very extended and continued up to October and November only closing with the onset of the dry season.

Parasitism: The most important parasite of *Tragocephala* in Nigeria is the egg parasite *Aprostocetus* sp. nr. *diplosidis* Crawf. (Hymenoptera: Encyrtidae) though large unidentified ichneumonids were bred from pupal cells from Egbeda, Ibadan Province in August and October 1960. Further natural control was found to result from the invasion of attacked twigs by *Hypothenemus pusillus* Egg. (Coleoptera: Scolytidae) which usually entered the dead or dying wood through the oviposition slit made by *Tragocephala*. From 255 attacked stems examined 169 eggs were obtained, of which 43 had been damaged by

H. pusillus including 14 parasitized eggs. A further 74 parasitized eggs were found amongst those undamaged by *H. pusillus*.

The mean number of parasites emerging from a single egg was 11.8 and the sex ratio was 1 male to 2.66 females.

Effects of Tragocephala attack: Due to the large number of eggs which fail to hatch or are lost most of the damage results from ring-barking alone. Young seedlings may be prevented from forming a jorquette and the subsequent regeneration by chupons from behind the damaged apex may be attacked in turn so that *Tragocephala* attack may be regarded in some localities as a major limiting factor in the establishment of new cocoa farms.

Scarabeidae

A small melolonthid beetle, *Aulacoserica* sp.? nov. (near *konduensis* Moser) (identified by Mr J. L. Gregory of the Federal Department of Agricultural Research) was noted attacking the flush leaves of seedlings. Attacked leaves had a typical net-like appearance, the lamina being devoured and the veins often left intact.

During the day the beetles are normally inactive and hide at the base of the plants, either under soil litter or beneath pots in the case of nursery plants. At dusk they emerge and commence feeding. They appear to be polyphagous and are attracted to ultra-violet light.

Scale insects

An undetermined species of *Asterolecanium*, identified by the Commonwealth Institute of Entomology as close to the cosmopolitan *A. pustulans* Ckll. (Homoptera: Asterolecaniidae) was found infesting twigs of cocoa at Akure, Ondo Province. It appeared to be associated with stem swellings somewhat similar in appearance to those produced by swollen shoot viruses, but probably the 'pit and gall' deformation commonly associated with *A. pustulans* on other host plants.

Spider mite

Specimens sent to the Commonwealth Institute of Entomology have been returned as an apparently undescribed species of *Tetranychus* (Tetranychidae).

In Nigeria spider mite attack on cocoa seems to be principally troublesome in nurseries and young plantings. The underside of leaves become infested though the upper surface and the unhardened apical regions of the stem may also be affected.

Seasonal changes in population levels of some minor pests

In the Gambari Shot-Hole Borer Experiment I, where the effects of several cultural treatments on the incidence of attack by *X. morstatti*

TABLE 41

*The distribution between shaded and unshaded seedlings of total lepidopterous larvae collected during the six months
October 1960 to March 1961*

<i>Species/Family</i>	<i>E. biplaga</i>	<i>L. phoenicochlora</i>	<i>A. leona</i>	<i>Lymantriidae</i>	<i>Limacodidae</i>	<i>Psychidae</i>	<i>Others</i>	<i>Totals</i>
No shade	40	1	3	0	8	38	13	103
Shade	37	21	27	5	7	29	29	155
Totals	77	22	30	5	15	67	42	258

on seedling cocoa were studied, records have also been kept of changes in the incidence of most minor pests.

Since November 1960 all lepidopterous larvae have been collected and returned to the laboratory for identification at monthly intervals. The distribution of all Lepidoptera, collected during the five month period, between shaded and unshaded plants is given in Table 41. Table 42 shows the general trend of aggregate populations during this period.

TABLE 42

Changes in aggregate numbers of Lepidopterous larvae on seedlings under shade and seedlings not shaded

(November 1960 to March 1961)

	<i>November</i>	<i>December</i>	<i>January</i>	<i>February</i>	<i>March</i>	<i>Totals</i>
No shade	69	17	12	1	4	103
Shade	80	36	23	11	5	155
Totals	149	53	35	12	9	258

Except in the case of the Psychidae, which develop slowly, it is unlikely that population estimation by total collection has had much influence on these data. None of the species concerned is specific to cocoa and as the plot in which these records were taken is relatively small, re-infestation from neighbouring forest and cocoa areas is probably both easy and rapid.

It is uncertain to what extent these data on Lepidoptera reflect the true association of the various species and/or families with shade or lack of shade and associated microclimatic factors or to what extent they concern the physical conditions of the plants under different treatments. It is probable that *Lophocrama phoenicochlora* and *Anomis leona* are definitely associated with shade, especially as most of these insects were collected in the first three months when differences between the physical condition of shaded and unshaded plants were not as great as they became subsequently.

The mean leaf number and percentage of seedlings flushing declined during the period, but it is not suggested that, with lepidopterous populations at such relatively low numerical levels, the changes in numbers observed were necessarily directly due to a decreasing food supply, though a close association between mean leaf numbers and numbers of lepidopterous larvae can be demonstrated. Due to the relatively low numbers of individuals of each species and/or family it is not yet possible to analyse the data on a species basis.

Table 43 shows the changes in percentage of plants infested by pests other than Lepidoptera during a six month period that included

TABLE 43

Fluctuations in incidence of several minor pests of cocoa on shaded and unshaded seedlings during the period October 1960 to March 1961 (Expressed as percentage plants infested)

	Shaded plants						Unshaded plants					
	F. virgata	Other M'bugs	Aphidae	Psyllidae	Thrips	Spider mite	F. virgata	Other M'bugs	Aphidae	Psyllidae	Thrips	Spider mite
Oct.	3.6	3.9	2.9	0.4	0.7	7.1	3.9	4.6	0.7	0.7	0.4	10.0
Nov.	4.6	3.9	14.6	0.4	0.7	8.2	5.0	3.9	1.1	1.1	1.1	6.1
Dec.	4.3	2.5	2.9	12.9	1.4	24.6	2.1	1.8	0.0	3.2	1.8	16.8
Jan.	5.7	0.4	0.0	44.6	6.8	17.5	4.7	0.4	0.0	6.1	3.2	5.1
Feb.	10.0	1.1	0.0	11.1	6.4	15.0	4.5	0.0	0.0	3.8	3.4	2.3
March	12.9	2.9	0.0	2.9	0.4	10.7	5.6	0.0	0.0	0.0	1.3	3.0

the whole of the 1960/61 dry season. It can be seen that the peak periods of most of these differ from each other and that none behaves in a way comparable with aggregate lepidopterous populations.

AGRONOMY

(G. H. Freeman)

SPACING EXPERIMENT

The land taken over with the Gambari Experimental Station includes an Amelonado spacing experiment planted in 1942. The design is a 7×7 Latin Square and the results obtained up to 1955-56 were published by Kowal (*Emp. J. exp. Agric.*, **27**, 138, 1959). Since then, further records have been taken by the Research Division, Ministry of Agriculture and Natural Resources, Western Region, and later by W.A.C.R.I. Yield records are given in Table 44, that for 1956-57 being based on good pods only, those for other years on all pods. A conversion factor of 12 pods to 1 lb. of dry cocoa has been used, though there is reason to believe that this gives an underestimate of the yield of dry cocoa from this area. The records for the seasons 1956-57, 1957-58 and 1958-59 are based on all the experimental trees in the plot. As shown by Kowal, the number of trees in 1956 was already well below the number originally planted; there are fewer still now, but the exact number in any one season is not known. In 1959-60 individual plots were not recorded, but the total number of pods from all trees, including guards, was 105,845, as compared with 109,940 in 1958-59. In 1960-61 the area was used for a black-pod spraying trial and a known number of trees were recorded in each plot. The pods per tree are thus known exactly, and the crop in lb. per acre was calculated from these trees. It can be seen from Table 44 that the crop per acre rises consistently as the spacing is reduced.

NURSERY TRIALS

The trials conducted in the season 1958-59 and 1959-60 and described in the appropriate annual reports (*Rep. W. Afr. Cocoa Res. Inst.*, 1958-59, p. 78 and 1959-60, p. 76) gave rather different results in the nursery. One possible reason for these differences was the time of sowing, December in 1958 but October in 1959. A trial was therefore planted at Gambari in 1960-61 in which one of the treatments was time of planting: beans were sown on four dates at intervals of four weeks, the first being in mid-November and thus the last in early February. The main plots of the trial had no shade, light shade and heavy shade, and were replicated twice. Sub-plot treat-

TABLE 44
Yields from the Amelonado spacing trial planted in 1942 at Gambari

Spacing	15' × 15'	12' × 12'	10' × 10'	7½' × 7½'	7½' × 6'	6' × 6'	5' × 5'
Dry cocoa per acre (lb.)							
1956-57	194	365	291	605	540	744	730
1957-58	161	288	216	363	400	458	422
1958-59	666	853	713	1,611	1,449	1,726	1,808
1960-61	521	652	741	1,241	1,405	1,599	1,863
Pods per tree	32.3	25.9	20.4	20.5	17.4	15.9	12.8

ments in addition to times of planting were frequency of watering and type of pot. The two frequencies of watering chosen were every second day and twice a week, corresponding to the two more frequent waterings of the 1959-60 trial. 'Whalehide' pots have been used in Nigeria in the past, and this trial afforded a good opportunity to compare them with some new polythene pots. There were thus 16 sub-plots within a main plot, each sub-plot containing 24 plants in 4 rows of 6 with a guard plant at each end of the row; the rows were in two pairs close together, with a gap of one foot between the pairs of rows. The rows ran North-South and there was one whole guard row at the East and West end of each main plot. The beans in the unshaded plots were sown 2 in. deep to reduce drying out prior to germination; for consistency this depth of planting was also used under shade. All the beans used in this trial were from open-pollinated T60, an Upper Amazon selection; the trees from which the beans were obtained were in an area containing only Amazon varieties.

Germination of the beans was good at all times, though somewhat delayed by severe Harmattan conditions following the November and February plantings; in November 11 per cent of the beans failed to germinate. The only other poor germination was in January, when in one of the heavily shaded plots there was 18 per cent failure. All the seeds in the main plot were sown by one man, whose non-experimental sowings also had a high failure rate; his result points to the need for very careful supervision of labour. Some plants that had germinated, particularly with no shade, failed to survive the prolonged dry season.

Growth records taken at four-weekly intervals showed consistent differences between the shade treatments and, for unshaded plots only, between the frequencies of watering. Mean values for height in inches and leaf number per plant in March, 5 weeks after the last planting date and thus 17 weeks after the first, are shown in Table 45. This shows that the treatment effects were not quite the same for all times of planting, the unshaded plants being at their worst when the planting time was quickly followed by Harmattan. Leaf area measurements were not taken but observations tended to confirm the result reported in the 1958-59 trial that the leaves were smallest in the unshaded plots. The total leaf area was apparently greatest under light shade, the treatment with the tallest plants, and thus it is tentatively suggested that this provides the best conditions for growth in the nursery. However, a final check on any nursery method cannot be obtained until the plants have been grown on, and so, as with the previous trials, the seedlings will be planted out in the field and further observations made.

TABLE 45
Measurements on cocoa seedlings in the nursery in March

<i>Time of planting</i>	<i>No shade</i>		<i>Frequent watering</i>		<i>Light shade</i>		<i>Heavy shade</i>	
	<i>Infrequent watering</i>	<i>Leaves</i>	<i>Height</i>	<i>Leaves</i>	<i>Height</i>	<i>Leaves</i>	<i>Height</i>	<i>Leaves</i>
November	8.4	15.0	10.8	18.8	13.6	15.5	12.7	13.3
December	7.6	13.5	9.4	17.5	10.4	11.9	9.9	10.0
January	4.7	8.0	6.0	8.6	7.5	8.8	7.6	7.4
February	1.6	1.8	3.7	4.0	6.3	4.6	7.1	4.5

5 per cent significant difference between the two frequencies of watering with the same shade treatment and time of planting: 1.10 for height and 1.61 for leaves.

5 per cent significant difference between two shade treatments at the same time of planting: 0.76 for height and 1.76 for leaves.

Type of pot had very little effect in the nursery, the polythene pots being, if anything, slightly better. If this result is confirmed in the field, polythene pots will be recommended for subsequent use. They are much lighter and cheaper, and can be made to any specification as to size, shape and thickness. A small experiment to compare two types of polythene pot did not show any differences, but if polythene is to be used on a large scale, further trials can readily be conducted.

STATISTICS

(G. H. Freeman)

Careful planning is necessary to make best use of the large area available for experiments at Gambari, and a Plots Committee has been formed and has met twice. Time has also been devoted to the detailed examination of past results, for example those of the spacing trial mentioned above. Statistical advice has been given to other members of staff of this Institute and at the request of officers of the Federal Department of Agricultural Research Division, Ministry of Agriculture and Natural Resources, Western Region. One trial planned for the Western Region Research Division had some interesting statistical features, and a paper describing these has been written and submitted for publication.

FUNGICIDES RESEARCH

(E. C. Hislop and P. O. Park)

LABORATORY STUDIES

Bio-assay of fungicides on detached pods

A total of thirty fungicide preparations have been tested for toxicity to *Phytophthora palmivora* Butl. by the method described (*Rep. W. Afr. Cocoa Res. Inst.*, 1959-60, p. 80).

The fungicide preparations have been code numbered and the composition of each is listed in Table 46.

The major fungicide comparisons made are listed in Table 47. Fungicide efficiency decreases from left to right in the table and any two treatments not underscored by the same line are significantly different ($P=0.05$) while differences between treatments which are underscored by the same line are not significant at the same level. Unless otherwise stated the concentrations of suspensions of fungicides containing copper are 0.02 per cent w/v copper. Concentrations shown in the table are in terms of the formulation w/v.

TABLE 46

The percentages of active ingredients in fungicide preparations tested

<i>Formulation Code Number</i>	<i>Active ingredients</i>
1	15% Streptomycin + 1.5% oxytetracycline
2	Bordeaux mixture, $(\text{CuSO}_4 \cdot 5\text{H}_2\text{O} : \text{CaO} :: 10 : 4) = 0.02\%$ copper
3	20% triphenyl tin acetate
4	50% copper as cuprous oxide
5	Carbide Bordeaux mixture $(\text{CuSO}_4 \cdot 5\text{H}_2\text{O} : \text{CaO}_2 :: 10 : 4) = 0.02\%$ copper
6	20% copper as copper oxychloride
7	45.5% copper as copper oxychloride
8	54% copper oxychloride + 32% zinc dimethyldithiocarbamate
9	50% copper as copper oxychloride
10	80% zinc dimethyldithiocarbamate
11	37.5% copper as copper oxychloride + 15% zinc ethylene bis-dithiocarbamate
12	65% zinc ethylene bis-dithiocarbamate
13	20% copper as copper oxychloride
14	35% copper as copper oxychloride
15	50% copper as copper oxychloride
16	1.58% mercury as phenyl mercury nitrate
17	50% copper as oxychloride + 0.6% mercury as phenyl mercury chloride
18	50% copper as copper oxychloride + (X)% organic mercury
19	40% copper as cuprous oxide
20	40% copper as cuprous oxide
21	50% copper as cuprous oxide
22	50% copper as cuprous oxide
23	50% copper as cuprous oxide
24	50% n-trichloromethylmercapto-4-cyclohexene 1, 2-dicarboximide
25	50% copper as copper oxychloride
26	89.5% copper acetylacetonate
27	73% sulphur
28	Standard laboratory Bordeaux mixture. (Copper:Calcium::1:1.65)
29	X% zinc dimethyldithiocarbamate + y% basic copper sulphate
30	Bordeaux mixture. $(\text{CuSO}_4 \cdot 5\text{H}_2\text{O} : \text{CaO} : \text{Water} :: 10 : 10 : 100)$
31	Untreated controls

Certain general trends amongst the fungicides containing copper were detected:

1. No formulations were consistently better than the Bordeaux mixtures (Code Nos. 2, 5 and 28).
2. Some cuprous oxide formulations (Code Nos. 4, 20, 21 and 22) were not significantly inferior to Bordeaux mixture.
3. Copper oxychloride formulations (Code Nos. 7, 9, 14, 15 and 25) were generally inferior to cuprous oxide.

Economically the most promising of the mixed and organic fungicides were two formulations containing captan (Code No. 24) and triphenyl tin acetate (Code No. 3) respectively.

Some of the results in Table 47 would seem to contradict these general trends. For example, in comparisons 11 and 14 the formulations (Code Nos. 4 and 23) both contain 50 per cent copper as

TABLE 47

Summary of the major fungicide comparisons. Fungicidal efficiency decreases from left to right but code numbers underscored by the same line do not differ significantly ($P=0.05$)

Comparison							
1	2	24	3	30			
		0.01%*	0.005%				
2	2	5	4	13	6	9	31
3	28	26	16	27	10	1	31
		0.04%	0.04%	0.04%	0.025%	0.1%	
4	24	2	3	12	29	14	31
		0.04%	0.02%	0.031%	0.04%	0.04%	
5	2	13	6	19	4	11	31
6	2	22	20	17	9	8	31
						0.04%	
7	28	18	17	8	11	31	
8	28	22	21	4			
9	21	4	22	9			
10	28	22	21	4			
11	28	21	4†	25			
12	21	15	7	31			
13	21	25	31				
14	21	23†	31				

* Unless otherwise stated the concentrations of suspensions of copper-containing fungicides are 0.02% copper W/V. Concentrations shown in the table are in terms of the formulations W/V.

† See text.

cuprous oxide but were relatively inefficient. Both of these products were found to have deteriorated during storage and have since been withdrawn by the manufacturers. The technique of bio-assay would therefore appear to provide a possible rapid and cheap method for the detection of deteriorated or inferior products, particularly when accompanied by tenacity tests.

Other anomalies which appear in Table 47 concern the copper oxychloride formulations (Code Nos. 13 and 6) which are considerably better than would be expected from the general trends outlined. Both these products however consist mainly of near-colloidal particles, and because of the higher cost of manufacture might not be so economical as non-colloidal preparations of the same copper content.

The less effective control of *P. palmivora* by copper oxychloride formulations compared with cuprous oxide formulations has been re-examined by the test tube dilution technique used in conjunction with slide germination tests. When suspensions of a copper oxychloride and a cuprous oxide formulation containing the same amount of copper and of similar particle sizes were compared, the LD 50 levels of the active ingredients were very similar. The colloidal suspensions of copper oxychloride mentioned above were considerably more toxic than any other fungicide containing the same amount of copper and it is believed that this is entirely due to the physical characteristics of the active ingredient. The *in vitro* tests did not provide any explanation for the relative failure of copper oxychloride formulations noted in Table 47, rather, on the basis of this test alone, one would have expected formulations Code No. 9 to be better than Code No. 22.

Persistence of fungicides on pods

An apparatus for testing the effect of artificial rain on pesticide deposits has been built. Water drops are formed at glass capillary orifices and allowed to fall through six feet onto batches of four fungicide treated pods suspended in wire cages. The tenacity of a number of copper formulations has been examined with this apparatus, the proportion of an estimated initial deposit remaining after exposure to a given amount of rain being determined chemically. A tenacity equation of the form: $\log W = \log W_0 - b \log (R + 1)$ has been obtained where W is the mean residue in $\mu\text{g. copper per sq. cm. pod surface}$ after the rainfall of R -inches, W_0 is the initial deposit in $\mu\text{g. copper sq. cm.}$ and b is a constant dependent on the fungicide (the leaching coefficient). The values of the laboratory leaching coefficient b for ten copper fungicide formulations are given in Table 48.

TABLE 48

Values of the leaching coefficient b for a range of copper fungicide formulations

Formulation No. <i>b</i>	2	30	4	5	6	9	15	20	22	23
	0.092	0.145	0.520	0.124	0.149	0.131	0.121	0.235	0.158	0.283

The residues remaining on the pod surface after increasing rainfall when the spray deposits of fungicide (Code No. 22) had dried at 75 per cent relative humidity (R.H.) for various time intervals have also been determined. When drying was incomplete, weathering was rapid and usually did not follow the tenacity equation. At 75 per cent R.H. deposits of formulation Code No. 22 weathered only slowly after a drying period of two hours but at 95 per cent R.H. a drying period of more than eleven hours was required to give subsequent slow weathering.

The high leaching coefficients of formulations Code No. 4 and 23 are no doubt due to the deterioration of the products during storage, confirming the results of the bio-assay studies.

The general conclusion drawn from these laboratory studies on fungicides tenacity are that most of the formulations tested adhere to the pod surface well, provided they are not rained upon before they are completely dry.

FIELD STUDIES

Tenacity of fungicides

Individually labelled Amelonado pods on trees were sprayed to run-off with 0.4 per cent aqueous suspensions of fungicides (Code No. 5, 9 and 22). Thirty pods of approximately half the average mature size were used for each treatment. The surface area of the pods was measured at the time of spraying and again when the pods were harvested at varying time intervals during the succeeding two months. The rainfall during these intervals was recorded. The fungicide deposits remaining on the pods was determined in the usual way. The residues determined were corrected for the increase in pod area which had occurred since spraying.

The results of these field studies did not show close agreement with the laboratory results. In some comparisons a rapid loss of fungicide deposit occurred between the time of spraying and the second sampling two days later, and it is obvious from the laboratory results that the deposits were rained upon before they were properly dry. The field results did confirm however that the small proportion of the initial deposit remaining was held tenaciously. The values of the leaching coefficient b for formulations weathered in the field are given in Table 49.

Since dew derived from the high relative humidities and/or rainfall can ensure that the surface of cocoa pods remains moist for many hours it is not surprising that the value of the leaching coefficient obtained in the field (Table 49) is higher than the laboratory value. Thus, if the results of the laboratory and field experiments are

TABLE 49

Values of the leaching coefficient b for three fungicides as determined in the field

Formulation No.	5	9	22
Experiment 1	—	0.08*	0.16*
Experiment 2	0.33	—	0.52

* For the range 1–15 in. rainfall.

considered together it appears that the high tenacity shown by most of the fungicides when completely dried (low values of b in Table 48) may well not occur in the field, where high humidities and frequent rainfall do not allow full drying. The initial deposit of 5–10 μg . copper per sq. cm. will be reduced more rapidly than the tabulated values of b indicate (Table 48).

A further factor leading to attenuation of the deposit on the pod surface is growth of the pod. In order to determine the increase in surface area with time the long and short axes of a number of pods were measured at weekly intervals throughout growth. The surface areas increased according to approximately sigmoid relationships. If the areas, expressed as a percentage of the final area, are plotted against time on linear probit paper straight line growth curves are obtained during most of the growth period. At the maximum period of growth the area doubles in 10 days and at least a 5-fold increase occurs during 2 months. Even if a fungicide film were to expand uniformly with the increasing surface area of the pod, and without developing cracks, growth alone would reduce the deposits to marginal or ineffective levels in about a month. The effect of weathering will be superimposed upon this attenuation by growth.

The efficiency of protective fungicides against *P. palmivora* depends on the maintenance of a complete film of toxicant over the whole surface of the pod of density sufficient to inhibit spore growth. From the laboratory and field studies it appears that for copper fungicides applied evenly over the cocoa pod surface the required minimum density is 1.0–1.5 μg . copper/sq. cm. This density is, however, only effective if the pods are sprayed properly and all parts of the pod receive the initial cover of fungicide. It is possible that overall cover may be aided by the use of spreader in the formulation. The surface tensions of the ten formulations, when suspended at 0.2 per cent copper, were determined by a du Nouy balance and are tabulated in Table 50 together with an indication of the relative efficacy of the fungicides as derived from laboratory or field trials. From these figures there is little evidence that the lower surface tensions are

correlated with efficacious formulations. It would seem therefore that it is careful spraying from at least two directions which is of prime importance in ensuring good cover.

TABLE 50

Surface tension of aqueous suspensions (0.2 per cent Cu) of fungicide formulations

Fungicide No.	2	30	4	5	6	9	15	20	22	23	Water
S.T. dynes/sq. cm.	71	71	63	71	56	61	72	41	50	57	72
Efficacy	**	**	**	**	*	o	o	**	**	*	

** = An efficacious fungicide for black-pod control.

* = A moderate fungicide.

o = A poor fungicide.

Fungicide spraying trial

A trial has been completed at Gambari in which six fungicide formulations and an untreated control were compared. The copper fungicides, (Code No. 22, 20, 9 and 17) were applied at a concentration of 0.2 per cent copper and Code No. 2 at 0.25 per cent copper. Code No. 8 was applied at 0.3 per cent w/v of the formulation.

The site chosen was a cocoa spacing trial with a 7×7 , non-orthogonal Latin square design and one treatment was applied to each column of spacing regimes. It was realized from the outset that this lay-out, in which treatments were confounded with columns, was not ideal but it was the only available area.

Trees were selected from each plot of about $1/12$ acre and were numbered. A total of 422 trees were recorded for each treatment, and the numbers of trees chosen from the various spacings are shown in Table 51.

TABLE 51

Numbers of trees chosen from the various spacing regimes

Spacing	Number of trees
5' $\times$ 5'	120
6' $\times$ 6'	90
6' $\times$ 7½'	75
7½' $\times$ 7½'	60
10' $\times$ 10'	36
12' $\times$ 12'	25
15' $\times$ 15'	16

TABLE 52

Summary of the total numbers of pods and the percentage of black pods harvested from all replicates at each harvesting date

Treatment	Formulation code number											
	20			8			2			31		
Date	Total pods	Black-pod %	Total pods	Black-pod %	Total pods	Black-pod %	Total pods	Black-pod %	Total pods	Black-pod %	Total pods	Black-pod %
7/6/60	1,166	3.8	1,080	6.7	1,477	2.4	1,501	5.0	1,477	6.9	1,323	1.8
27/6/60	816	5.4	685	5.7	734	3.5	841	9.7	1,037	2.2	1,228	1.3
18/7/60	286	11.9	196	16.8	243	17.7	391	33.3	301	18.6	280	25.4
8/8/60	72	33.3	165	57.0	145	44.8	286	77.2	168	41.1	222	55.1
29/8/60	197	56.9	289	59.2	315	51.1	414	86.6	324	52.1	451	65.4
19/9/60	373	61.7	313	71.2	323	60.7	599	91.5	457	73.0	545	47.3
11/10/60	1,274	44.5	1,043	57.4	769	39.3	942	79.9	1,315	55.2	1,583	64.9
31/10/60	1,595	58.1	1,392	66.0	976	32.5	980	69.5	1,466	55.4	1,717	59.6
21/11/60	593	29.2	638	29.5	722	16.6	484	52.0	1,054	29.0	1,292	44.4
Final*	567	30.8	571	29.4	601	27.0	541	38.1	625	29.6	724	37.1
Total/Average black-pod %	6,939	33.6	6,372	39.3	6,305	23.1	6,979	47.4	8,224	33.8	9,365	41.0
												7,632
												43.2

* See text.

The first spraying was carried out on 17th May and a total of nine sprayings were applied at three-weekly intervals, using 'Four Oaks' pressurized knapsack sprayers fitted with No. 51 nozzles as recommended for use by farmers by the Ministry of Agriculture and Natural Resources, Western Nigeria, and operated at an initial pressure of 45 lb./sq. in. The spray liquid was directed at individual pods from two directions to ensure complete coverage, and was applied until run-off occurred. Pods high in the canopy of trees were treated by a 'jetting' technique. The swirl plate was removed from the sprayer nozzle and a narrow stream of spray liquid was directed up at the pods under pressure. The volume of spray liquid used varied at different times in the season between 10 and 40 gallons per acre depending upon the number of pods on the trees.

One pre-spray harvest was carried out and, subsequently to this, harvesting immediately preceded each spraying period. A final harvest was taken three weeks after the last spraying date. The numbers of ripe healthy pods and diseased pods yielded by each tree were recorded at each harvest. Diseased pods were removed from the trees at each harvest whether or not they were ripe.

The total numbers of pods and the percentage of black pods harvested at each date are detailed in Table 52.

The final harvest figures in Table 52 are based on a count of all healthy mature pods the vast majority of which would have remained healthy because natural incidence of black-pod was declining. To these were added the diseased pods and a considerable number of small dead pods which were removed from the upper branches where they had been missed in previous harvests.

The data of this trial have been analyzed by two different methods and although the results vary a little the order of fungicide efficiency can be summarized thus:—

2	20	22	8	9	17	31

where fungicide effectiveness decreases from left to right and products underscored by the same line are not significantly different at the 5 per cent level of probability.

It is interesting to compare laboratory comparison No. 6 in Table 47 with the field results given above. The order of fungicide efficiency in the laboratory was:

2	22	20	17	9	8	31

This result is similar to the field result and in fact shows close agreement when the following facts are taken into consideration. Formulation Code No. 2 was significantly superior to all treatments in the field and whereas this was not so in the laboratory comparison No. 6, there have been indications throughout the laboratory testing that it is sometimes better than treatments Code No. 20 and 22. In the field trial, treatment Code No. 8 only just qualified to rank with treatments Code Nos. 20 and 22. The relative inefficiency of treatment Code No. 17 in the field can to some extent be explained by the poor physical characteristics of the formulation which would be expected to show up more in a field trial than in the laboratory.

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Swollen shoot virus has been transmitted mechanically to cocoa from *Adansonia digitata* L. *Bombax brevicuspe* Sprague. Infective slurries were prepared by macerating leaves from infected plants in a cold solution (4-10°C. pH 8 or 8.5) containing phosphate, cysteine and usually ethylenediamine tetraacetate. The virus was also transmitted from infected to healthy *A. digitata* but only after concentration of clarified sap by dialysis against concentrated sucrose solution (50 g. sucrose per 100 ml. solution) and ultrafiltration.

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Brunt, A. A. and Wharton, A. L. (1961): 'A gall disease of cocoa (*Theobroma cacao* L.) in Ghana. *Proc. Sixth Commonw. mycol. Conf.*, London, 1960, pp. 148-156.

Cunningham, R. K., Smith, R. W. and Hurd, R. G. (1961): 'A Cocoa Shade and Manurial Experiment at the West African Cocoa Research Institute, Ghana. II. Second and Third years'. *J. hort. Sci.*, 36, pp. 116-125.

The yields, harvest distribution and soil data of the second and third year of a shade and manurial experiment on bearing cocoa are presented and discussed. A mineral nutrient balance sheet has been drawn up and the effect of the various treatments on pod and bean size has been given. Provided all other important growth-limiting factors are adequately controlled, cocoa yields are highest without shade. The need for fertilizer is greatest without shade, and the drain of nutrients from the soil by cocoa only becomes excessive when yields approach 2,000 lb. dry cocoa per acre.

Entwistle, P. F. (1960): 'A review of the problems of shot-hole borer (Coleoptera, Scolytidae and Platypodidae) attack in cocoa in West Africa.' *Proc. Eighth Inter-amer. Cacao Conf.* pp. 208-223.

Freeman, G. H. (1961): 'Some further designs of type O:PP.' *Ann. math. Statist.*, 32,

A new method of deriving designs of type O:PP is described. The method gives rise to some designs previously obtained by other methods, and also to some entirely new designs. These new designs are described in detail and a worked example given.

Glendinning, D. R. (1960): 'Selfing of Self-incompatible Cocoa'. *Nature, Lond.*, 187, pp. 170.

Glendinning, D. R. (1960): 'The relationship between growth and yield in cocoa varieties'. *Euphytica*, 9, pp. 351-355.

Cocoa varieties of very high vigour have recently been bred in West Africa, and decisions on which of them to issue to farmers must be made without protracted testing. Growth records in conjunction with early yields are therefore being used for selection.

Correlations exist between the rate of growth before bearing and the total yield up to five years old, which for some varieties is as much as a ton of dry cocoa to the acre. These arise at least partly from the faster growing varieties reaching bearing size earlier, so do not prove a relationship between growth rate and long-term yield.

After commencement of bearing vegetative growth slows, and there is a high correlation between the reduction in growth rate and the total yield. This suggests that an equation $\text{GROWTH RATE BEFORE BEARING} = \text{GROWTH RATE WHILE BEARING} + \text{YIELD}$ may be used. A high yielding variety will thus be one of vigorous early growth which is later relatively greatly reduced. No advantage to larger trees is expected in West Africa as a close spacing is always used.

Certain varieties have been consistently among the most vigorous in a series of young trials planted in different parts of Ghana, so it seems likely that the best varieties will prove suitable over a wide range of conditions.

Glendinning, D. R. (1960): 'Plant Breeding at the West African Cocoa Research Institute'. *Proc. Eighth Inter-amer. Cacao Conf.*, pp. 374-377.

Glendinning, D. R. (1961): 'Problems in the Assessment of Cocoa Varieties'. *Ghana J. Science*, 1, pp. 38-43.

Glendinning, D. R. (1961): 'Natural Pollination of Cocoa'. *Nature, Lond.*, in press.

Hall, T. H. R. (1961): 'A note on the Pruning of Amazon Cocoa in Ghana'. *Trop. Agriculture, Trin.*, 38, pp. 333-336.

The results of a pruning trial carried out at Tafo, Ghana, on Amazon cocoa show that pruning, by restricting growth to the first jorquette, has a limiting effect on the yield. It is suggested that this method of pruning may not be the most advantageous, while consideration may well be given to pruning methods adopted for other perennial fruit crops.

Hurd, R. G. and Cunningham, R. K. (1961): 'A Cocoa Shade and Manurial Experiment at the West African Cocoa Research Institute. III. Physiological Results'. *J. hort. Sci.*, 36, pp. 126-137.

Investigations have been made of the flowering and fruiting behaviour of cocoa trees after shade removal and fertilizer application. The considerably greater yields obtained were associated with increases in vegetative growth, in amount of flowering, and in setting and wilting of the young pods.

The treatments have increased the intensity, but have not affected the periodicity, of the rhythm of flushing and flowering observed in cocoa. This is in keeping with current ideas on endogenous rhythms in plants.

The percentage of the cherelles wilting remained unchanged in all the treatments despite the considerable differences in the absolute numbers present. An explanation of this is presented.

It is recommended that fertilizers are applied at the beginning of the main rains, with possibly a later foliar application to influence the developing crop.

Kay, D., Longworth, J. F. and Thresh, J. M. (1960): 'The interaction between swollen shoot disease and Mirids on Cocoa in Nigeria'. *Proc. Eighth Inter-amer. Cacao Conf.*, pp. 224-235.

Smith, R. W. (1960): 'The Spacing of West African Amelonado Cocoa in Ghana'. *J. hort. Sci.*, 35, pp. 176-184.

A spacing trial at W.A.C.R.I. is discussed in relation to yield, habit and general performance of the trees. It was concluded that, under the conditions of the experiment, a spacing of $7\frac{1}{2} \times 7\frac{1}{2}$ ft. was optimum for high yields and that, therefore, Amelonado cocoa in Ghana should be grown at approximately this spacing.

Turner, P. D. (1960a): 'Variation in *Phytophthora palmivora* (Butl.) Butl. on *Theobroma cacao* L. in West Africa'. *Nature, Lond.*, 186, pp. 495-496.

Turner, P. D. (1960b): 'A survey of *Phytophthora palmivora* on cocoa'. *Commonw. Phytopath. News*, 6, p. 29.

Turner, P. D. (1960c): 'Strains of *Phytophthora palmivora* (Butl.) Butl. from *Theobroma cacao* L. I. Isolates from West Africa. *Trans. Brit. mycol. Soc.*, 43, pp. 665-672.

Distinct strains of *Phytophthora palmivora* were found when 179 isolates from ten cocoa-producing countries were examined. Comparative tests showed the strains to differ in lesion development of cocoa pods, in sporangial dimensions and in geographical distribution. Results of nearly 900 crossing tests showed that the two dominant strains were sexually complementary, whilst another small group of isolates, atypical of *P. palmivora*, was complementary to neither of the other two. Classification and distribution of the strains are discussed.

Turner, P. D. (1960d): 'Complementary isolates of *Phytophthora palmivora* from Malaya'. *Mal. agric. J.*, 43, pp. 17-18.

Turner, P. D. (1961): 'Complementary isolates of *Phytophthora palmivora* from cacao and rubber, and their taxonomy.' *Phytopathology*, 51, pp. 161-164.

From an examination of over 200 isolates of *P. palmivora* from cocoa and rubber from 22 different countries, complementary strains of the pathogen were found on both hosts. In general, oospores were readily produced in mixed cultures of isolates from rubber and cacao. Justification for raising isolates from the two hosts to varietal level within the species is considered inadequate.

Turner, P. D. (1961): 'Strains of *Phytophthora palmivora* (Butl.) Butl. occurring in West Africa'. *Proc. Sixth Commonw. mycol. Conf.*, London, 1960, pp. 147-148.

Turner, P. D. and Wharton, A. L. (1960): 'Leaf and stem infections of *Theobroma cacao* L. in West Africa, caused by *Phytophthora palmivora* (Butl.) Butl.' *Trop. Agriculture, Trin.*, 37, pp. 321-324.

Leaf and stem infections of mature cocoa trees in West Africa caused by *P. palmivora* are described and illustrated. The symptoms are characteristic and identical in Ghana, Nigeria, Southern Cameroons, Fernando Po and Cameroun, where the disease is widespread but of infrequent occurrence and of only local importance. Comparison of leaf and stem isolates from these territories showed that they are the same as the two complementary strains of *P. palmivora* found attacking cocoa pods in West Africa. All types of damage to cocoa which are caused by *P. palmivora* in other continents are now known to occur in West Africa.

BALANCE SHEET
AS AT 31st MARCH, 1961

WEST AFRICAN COCOA

BALANCE SHEET

LIABILITIES						£G	s.	d.	£G	s.
SURPLUS ACCOUNT	...	...	...	...	...				1,933,363	5
SUNDRY CREDITORS	...	...	...	...	...	7,341	14	7		
PROVISIONS AND ACCRUED CHARGES	...	...	...	...	...	25,495	13	1		
									32,837	7
ADVANCES FROM JOINT MISCELLANEOUS FUND	...								60,000	0

(Sgd.) J. W. BLENCOWE, *Ag. Director.*(Sgd.) J. N. A. HYDE, *Accountant.*

 £G2,026,200 13 4

We have audited the above Balance Sheet of the West African Cocoa Research Institute and explanations that we have required. In our opinion and subject to our Report of examination of the Institute as at 31st March 1961, according to the best of our information and belief, the Balance Sheet is correct.

ACCRA,

14th August, 1961

SEARCH INSTITUTE

31st MARCH 1961

ASSETS							£G	s.	d.	£G	s.	d.
LAND AND BUILDINGS—												
Cost to 31st March 1960	...	...	...	...	...	...	461,316	15	6			
Additions during the year	...	...	...	...	...	...	47,157	0	8			
							508,473	16	2			
Less Amount written off	...	...	...	...	...	...	508,473	16	2			
FURNITURE AND EQUIPMENT—												
Cost to 31st March 1960	...	...	...	...	...	...	79,438	15	2			
Additions during the year	...	...	...	...	...	...	9,048	4	7			
							88,486	19	9			
Less Amount written off	...	...	...	...	...	...	88,486	19	9			
CURRENT DEBTORS—												
Staff Advances—Tafo	...	...	11,097	13	5							
—Ibadan	...	...	4,381	13	0							
							15,479	6	5			
Miscellaneous Debtors	...	...	...	...	...	...	1,400	1	0			
Deposits and Prepayments	...	...	...	...	...	...	3,351	9	7			
W.A.C.R.I. Club and School	...	...	...	...	...	...	136	2	0			
Sierra Leone Government—Grant Receivable	...	...	...	...	...	...	1,325	0	0			
										21,691	19	0
INVESTMENTS—At Cost—												
Timber	...	...	...	...	...	...	2,331	15	2			
Fuel	...	...	...	...	...	...	509	0	4			
Films	...	...	...	...	...	...	221	4	3			
Maintenance	...	...	...	...	...	...	12,623	4	5			
										15,685	4	2
INVESTMENTS—At Cost	...	...	...	...	...	...				1,966,861	17	7
Market Value at 31.3.61 (£G1,590,002 gs. 1d.)												
CASH, BANK BALANCES AND FUNDS WITH CROWN AGENTS—												
Cash on Hand—Tafo	...	...	...	...	...	...	633	3	2			
—Ibadan	...	...	...	...	...	...	47	0	2			
Bank of West Africa Limited—												
Current Account—Tafo	...	...	...	...	...	...	16,154	9	7			
—Ibadan	...	...	...	...	...	...	403	11	7			
Post Office Savings Bank	...	...	...	...	...	...	4,364	15	9			
Crown Agents—Current Account	...	...	...	...	...	...	358	12	4			
										21,961	12	7
								</				

I have examined the books and vouchers of the Institute and have obtained all the information attached hereto, this Balance Sheet sets forth a true and correct view of the financial position of the Institute and as shown by the Books of the Institute.

(Sgd.) CASSLETON ELLIOT & CO.
Chartered Accountants.

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